Chapter 3: Climate Change

Introduction

Warming of the Earth's climate has become evident over the last several decades, though there is still debate over the anthropogenic (or man-made) contribution to climate change. The overwhelming consensus among climate scientists is that human-derived sources of greenhouse gases have at the very least sped up, or even caused, the observed warming in the last century. In the most recent report from the Intergovernmental Panel on Climate Change (IPCC), which is a body of international scientists and climate experts established by the United Nations, the authors state: "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" (IPCC 2007).

In terms of managing water resources in a changing climate for a region as diverse and complex as the Inyo-Mono planning region, it is necessary to have access to information at scales that are meaningful for planning and decision-making. The Inyo-Mono IRWM process attempts to provide information at the appropriate scale. An additional challenge is that, given the remote and rural nature of the Inyo-Mono region, information regarding climate change impacts, greenhouse gas mitigation, and adaptation strategies originating from academic institutions, or State or federal agencies, is not always readily accessible. Thus, the Inyo-Mono RWMG is committed to improving availability of climate change-related information for water practitioners in the area, through the IRWM Plan, other targeted documents, and workshops. This chapter first presents information about expected climatic changes and their impacts on the Inyo-Mono IRWM region. Using this information, we then present a qualitative vulnerability analysis that demonstrates what aspects of the water management system in the Inyo-Mono region are the most vulnerable to climate change impacts. These vulnerabilities are prioritized, and the beginnings of a plan for data/information collection are presented. An examination of adaptation strategies presented in DWR's Managing an Uncertain Future is performed. We end with some first greenhouse gas emissions inventories performed for water systems in the region.

Climate Change Vulnerabilities and Impacts in the Inyo-Mono Region

Globally, air temperature has increased 1.3°F (0.7°C) over the last century (1906-2005) (IPCC 2007). This warming is not uniform, however. Polar regions are showing more warming than mid-latitude regions, at up to twice the global average rate in the last 100 years. High-elevation/mountainous regions are also experiencing increased warming. Trends in precipitation have also been observed, although not in consistent directions. Some areas, such as the Sahel, southern Africa, and parts of southern Asia have experienced decreased precipitation, while eastern North and South America and northern Europe have experienced increased precipitation. Other impacts related to these climatic changes include sea level rise, melting glaciers and polar ice caps, warming oceans, decreased snow cover, melting permafrost, droughts, and more extreme weather events. All of these changes are expected to continue, if not accelerate, in the coming decades.

While it is important to understand current global climatic trends, regional and local climatic changes are more pertinent to natural resources management, planning, and policymaking. It is possible to understand past climatic trends through observed data, where they are available. Yet in order to predict future climate, scientists must use models, which are inherently imperfect. General circulation models (GCMs) are most commonly used to incorporate information about greenhouse gas emissions and other elements of the atmosphere-ocean system. These models produce large-scale output based on grid cells on the order of several kilometers, which, in mountainous areas, is not a useful scale for natural resources planning and management. Efforts to downscale GCMs and to develop regional climate models (RCMs) have improved over the last few years, although there is criticism as to the accuracy of these smaller-scale representations.

Perhaps the most criticized part of using models to project future climate is the uncertainty inherent in these models. Each model contains different assumptions about the atmosphere-ocean system and parameterizes elements of the climate differently. Thus, each model delivers slightly different projections of future temperature, precipitation, and other climatic variables. To use just one model as an indication of future climate is problematic. Instead, the convention is to use an ensemble of several climate models to create a general picture of future climatic trends. In this way, the uncertainty of each model is accepted, but it does not prevent the use of climate models in climate change analyses.

One of the primary drivers of GCMs and RCMs are greenhouse gas (GHG) emissions scenarios. The IPCC has developed a set of possible future GHG emissions based on different scenarios of global population growth, economic growth, government regulations of GHGs, etc. (IPCC 2007). GCMs and RCMs incorporate these emissions scenarios to produce a suite of possible climatic changes.

In general, GCMs show good agreement with respect to temperature changes, showing long-term warming over the globe. There may be some exceptions to this warming. For instance, northern Europe, whose climate is moderated by the North Atlantic ocean circulation, may actually experience cooling if ocean currents slow. For California, there is strong consensus that temperatures will continue to increase in the coming century. Using two GCMs and two emissions scenarios, Hayhoe et al. (2004) found that summer temperatures are likely to increase more rapidly than winter temperatures (see also Cayan et al. 2008), and that the north and northeast portions of the state may warm more than the southwest portion. Furthermore, warming is expected to be greater further inland in California due to the moderating effects of the ocean on air temperature in the coastal regions (Cayan et al. 2008).

A regional climate modeling effort analyzed temperature and precipitation changes specifically for the ten California Department of Water Resources hydrologic regions (Snyder et al. 2004). The North Lahontan and South Lahontan regions (in which the Inyo-Mono planning region resides) exhibited larger temperature increases than the other hydrologic regions, particularly in winter months (Snyder et al. 2004). This difference is likely due to the high elevations in these regions as well as their inland locations.

Projected precipitation patterns are much less certain than projected changes in temperature. Despite widespread regional differences over the globe, high-latitude regions are expected to experience increased precipitation amounts, while sub-tropical regions are expected to dry (IPCC 2007). For California in general, the seasonal patterns of precipitation resulting from the Mediterranean-type climate are not expected to change (Cayan et al. 2008). Projections of changes in the magnitude of precipitation, however, are not as straightforward. While earlier projections of precipitation showed large increases by 2100, more recent projections show only slight increases or slight to moderate decreases (Cayan et al. 2008, Hayhoe et al. 2004). Thus, it is difficult to develop expectations of precipitation changes with much certainty. Models show that precipitation patterns will continue to exhibit considerable monthly, interannual, and interdecadal variability (Cayan et al. 2008, Hayhoe et al. 2004), which may serve to mask any medium-term change in precipitation trends.

Perhaps more significant for California water resources than direct changes in temperature and precipitation will be the impacts of these climatic changes to the hydrological cycle. In California, almost 75% of annual water resources originate and are stored in Sierra Nevada snowpack (DWR 2008). This natural reservoir captures and stores water in the winter, when it is least needed throughout the state, and slowly releases it in the spring and summer through snowmelt runoff and streamflow, when statewide precipitation is limiting. Climate change-induced alterations to the amount of snowpack and to the timing of snowmelt and streamflow can impact both the quantity and quality of water resources available to urban and agricultural users. Expected hydrologic changes specific to the Inyo-Mono region will be discussed throughout this chapter.

DWR, in conjunction with the U.S. EPA and the Army Corps of Engineers, released in late 2011 the *Climate Change Handbook for Regional Water Planning* (DWR, 2011). The analysis that follows is largely in step with the guidance provided in the handbook.

Region Characterization

Chapter 2 (Region Description) provides a thorough description of the Inyo-Mono planning region, including climate, hydrology, geography, watersheds and associated ecosystems, and water supplies and demands.

Climate Change Impacts

Water Supply

When thinking about climate change impacts to water resources in the Inyo-Mono region, we are most concerned with changes to winter snowpack and spring snowmelt and runoff. As with other regions in California that depend on water supplies from the west slope of the Sierra Nevada, snow provides a natural water reservoir for eastern Sierra Nevada communities and for the water that is exported to Los Angeles. Although changes in the amount of snow and rain received each year could impact water supplies, the projected impact of warming temperatures on the timing of snowmelt and streamflow is more certain and therefore may be of greater immediate concern. For years, water operators have depended on a peak in runoff during the late spring or early summer and have developed their water operations protocols accordingly. Changes in this timing will require development of flexible water operations protocols and better forecasting tools.

Already, changes in snowmelt runoff timing have been observed in western North America (Stewart et al. 2004). Snowmelt-dominated peak streamflow has shifted 10-30 days earlier since 1948 in many parts of the western U.S. (Stewart et al. 2004). It is expected that this trend towards earlier peak streamflow will continue throughout the 21st century, with many rivers eventually exhibiting a peak streamflow 20-40 days earlier than the mid-20th century (Snyder et al. 2004, Stewart et al. 2004). Models show that these observed and projected changes in streamflow timing are most likely caused by warming air temperatures rather than by changes in precipitation amounts (Stewart et al. 2004).

Although changes to the timing of events may be predicted to create the largest impacts to water supplies, changes in the amount of snowpack and other forms of precipitation can also have effects. Snowpack is expected to decrease in most areas of the West, both because of increased winter rain and more winter snowmelt due to higher temperatures (Snyder et al. 2004). Increased incidence of rain-on-snow events can cause winter flooding and help to speed up snowmelt and streamflow. Already, observed April 1 snow water equivalent (SWE), which is commonly used as the benchmark for measuring the amount of water delivered during the winter, has declined throughout the West, although not uniformly so (Mote et al. 2005). For the second half of the 20th century, the largest losses in April 1 SWE occurred in Washington, Oregon, and northern California, while the southern Sierra Nevada actually exhibited an increase in April 1 SWE (Mote et al. 2005). For the future, overall decreases in SWE are expected to continue and may perhaps even accelerate (Mote et al. 2005).

It is expected that the largest decreases in SWE will occur at lower elevations in western mountain ranges where the temperature currently hovers around freezing and will most likely increase. In the Sierra Nevada, the northern extent of the range will likely experience more dramatic impacts than the southern end of the range, which is higher in elevation. This projection may bode well for the Inyo-Mono region, which reaches from the central to southern Sierra Nevada. A much greater proportion of the snow zone of the eastern slope of the Sierra Nevada is at relatively high elevation than that of the western slope. This greater proportion of watersheds at elevations above those most likely to be impacted by changes in freezing level may also moderate hydrologic impacts of rising temperatures.

It is also expected that winters will become shorter and summers will be longer. Whether this results in an overall net loss in precipitation is unknown, but we might expect that snowfall that used to arrive in the autumn and spring might be delivered as rain in the future. This extended growing season will also mean more plant growth, which will increase the plant water demand.

As important but much less known are the impacts of climate change to groundwater supply. It might be expected that altered streamflow amounts and/or timing could affect recharge to groundwater basins in the region, but there are presently few data to support that assumption. However, as surface water supplies become more variable and unpredictable, communities, landowners, and resource managers may increasingly turn to groundwater to make up water supply deficits.

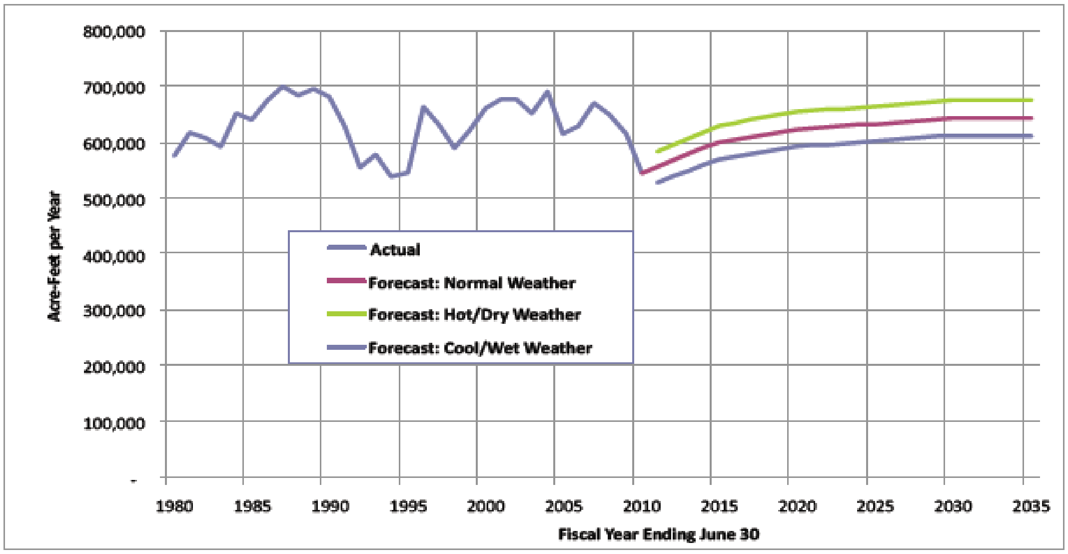
Water Demand

Because of the sparse population in the region, local water demand is not large. Demand does fluctuate seasonally to satisfy landscape irrigation and air conditioning needs (through the use of swamp coolers) in the summer. This seasonal demand could increase as summers become longer and warmer. Efforts to encourage native landscaping in communities throughout the region may help to mitigate some of this increase.

A second main source of water demand comes from the City of Los Angeles in the form of water exports from the Inyo-Mono region. The 2010 Los Angeles Department of Water and Power Urban Water Management Plan shows that, under average climate variability, overall water demand for the city is likely to increase slightly over the next 10-15 years and then level out around 2030 (LADWP, 2010; Figure 3-1). No analysis of demand under a changing climate is available. In general, it might be expected that demand from the Los Angeles Aqueduct will increase not only because of the expected increase in overall water demand, but because other sources used by the City, such as Colorado River water and State Water Project water, are likely to become increasingly unreliable.

Figure 3-1. Overall projected water demand for the City of Los Angeles through 2035.

Exhibit 2K
Water Demand Forecast with Average Weather Variability



Water Quality

Currently, most anthropogenic problems related to surface water quality in the region come from roads, recreation and grazing. While these activities do take place at high elevations, surface water quality high in the watersheds tends to be good. As high-elevation streams move downhill, anthropogenic impacts reduce the quality of the water. Climate change could impact water quality by intensifying summer recreation, which brings more visitors to the area than winter recreation. Longer growing seasons could also mean longer grazing seasons, and along with those, attendant impacts to water quality.

There are also naturally-occurring water quality contaminants in the region. These are mostly found in groundwater and largely occur as arsenic and uranium. Although there have been no known studies specific to impacts of climate change on groundwater quality in the region, altered recharge rates and amounts could impact the concentration of these substances in underlying aquifers. Additional groundwater pumping resulting from variable or unreliable surface water supplies may also increase the concentration of arsenic and uranium in the aquifer, depending on the mixing among layers. A current study in Mammoth Lakes by the Mammoth Community Water District will examine various layers of the underlying aquifer to determine if some sources are better than others, but the study will not be directly linked to climate change.

Flooding

Although the Inyo-Mono region does not experience flooding on the scale of the Sacramento-San Joaquin Delta or the Central Valley of California, localized flooding can be a major concern. Many communities on the Highway 395 corridor have experienced flooding from nearby streams and rivers, especially in years with large amounts of precipitation. In the Inyo-Mono region, flooding is typically a concern either (1) during rain-on-snow events in the winter or (2) during the spring snowmelt and runoff, although summertime flooding can occur as well. Some communities in the Inyo-Mono region have limited infrastructure to deal with large amounts of stormwater, which results in flooding. In the wildland areas of the region, flooding and erosion can become problematic especially after fire, and problems that originate upslope can affect downslope communities.

The more extreme weather events expected to accompany changes in the climate may have implications for flooding in the region. In particular, extremely large precipitation events or increased rain-on-snow events may be of concern. It is less clear whether the altered timing of snowmelt and streamflow will affect flooding in the region. The RWMG is working to better understand not only current flooding patterns and causes but also projections of future flooding.

Terrestrial and Aquatic Ecosystems

Impacts of a changing climate on terrestrial and aquatic ecosystems, and their living inhabitants, have been studied worldwide. From this research, some general principles have been established, although it is difficult to completely generalize as impacts are expected to differ ecosystem-to-ecosystem and even species-to-species.

One of the primary concerns related to climate change impacts on ecosystems is the movement of animal and plant species. If the climate in a species' current range changes to the point of being beyond that species' tolerance, the species must either adapt or move (Aitken et al. 2008). While some evidence of climate-related adaptation has surfaced, it has become more apparent that species are starting to move to more favorable climate regimes. This migration is particularly evident in mountainous and topographically-complex regions, such as the Inyo-Mono. As lower elevations warm, species may migrate to higher elevations in mountain ranges. This adjustment has already been observed in some bird species. Species may also shift their ranges north or south as the climate changes. However, direction of movement may not always be predictable. For example, while it is thought that most species in the Sierra Nevada will move up in elevation over time with a warming climate, some models show that, on the east side of the Sierra, the conifer forest could actually move down in elevation into the sagebrush steppe in certain scenarios of altered precipitation regimes (Lenihan et al. 2003).

Mobile animal species will have an easier time shifting their ranges than sessile plants. Plants will need to depend on seed dispersal and seedling establishment into habitat with more favorable climate. Furthermore, it is not expected that all species will move in the same direction – even species that currently reside in the same habitat or ecosystem. Such differences in movement will alter relationships among species and may create novel and unexpected consequences. For those species that are not able to migrate to more favorable conditions, local extirpation or even extinction may become a reality.

Climate change may favor some invasive plant and animal species, particularly if it places stress on their native competitors. Conversely, as species move, invasive species may encounter new competitors that are able to limit their spread. Again, such movement and interactions will vary by species and ecosystem. Although the Inyo-Mono region and adjacent Great Basin and Mojave deserts have been relatively free of invasive species, there are a few of considerable concern, including cheatgrass, red brome, quagga mussels, and zebra mussels.

Changes in hydrology may significantly impact aquatic ecosystems. Altered timing of streamflow and changes in flooding regimes are two physical changes that could impact these systems. Also, increased water temperature and associated impacts to other parameters such as dissolved oxygen, pH, and turbidity may affect fitness or survival of individuals and species. Given the importance of these aquatic systems to recreation, livelihoods, and the water supply of the region and distant urban areas, impacts to aquatic species are important to understand.

Climate Change Vulnerabilities

The Intergovernmental Panel on Climate Change defines vulnerability as "the degree to which a system is exposed to, susceptible to, and able to cope with and adapt to, the adverse effects of climate change." This section examines major vulnerabilities related to water resources following the categorized impacts of the previous section. The questions posed follow the guidance provided in the *Climate Change Handbook for Regional Water Planning* (2011).

Water Supply

1) Does a portion of the water supply in the region come from snowmelt?

Yes. All communities that utilize surface water originating from Sierra Nevada snowpack, and all communities that utilize groundwater recharged by infiltration of Sierra Nevada snowmelt, rely on snowmelt for water supply. This dependence on snowmelt includes both local communities and the City of Los Angeles.

2) Would the region have difficulty in storing carryover supply surpluses from year to year?

It depends. Given the sparsely-populated and rural nature of the region, there has not yet been a need for major water storage infrastructure. However, because of the Los Angeles Aqueduct, there is more storage in the region than might be expected. While currently, this infrastructure is only being used to store and convey water belonging to Los Angeles, there is potentially the capacity to use this infrastructure to help store surpluses from wet years for use by local communities. In other parts of the region outside of the Mono and Owens watersheds, new surface storage would need to be considered. Alternatively, water storage in underlying aquifers may prove to be a viable option, depending on changes in recharge rates, as several communities in the region are starting to look more seriously at conjunctive use. Yet small, rural water districts may have difficulty in finding increased storage capacity. Usually these water districts use small lakes or tanks to store water, and adding storage facilities is expensive.

3) Has the region faced a drought in the past during which it failed to meet local water demands?

There are several examples of inability to meet local water demands. First, the LADWP is required to provide irrigation water to its agricultural lessees. During the drought of 1976-1977, it sought to eliminate the supply of irrigation water so that it could meet the water needs for the City. Although it was not allowed to do so until adopting a water conservation plan, irrigation supplies were reduced during this time period.

During the 1988-1991 drought, the Mammoth Community Water District applied for emergency waivers to avoid requirements to comply with fishery bypass flows on Mammoth Creek in order to make more surface water available for community needs. In 2007 and 2012, both of which were drought years, MCWD instituted water restrictions on outdoor irrigation due to the lack of surface water availability and the necessity to use only groundwater.

In the Indian Wells Valley, communities are faced with perpetual drought conditions. The area receives, on average, less than four inches of rain per year. Thus, these communities fully rely on groundwater, which is being overdrafted at a rate of about 1.5 feet/year.

4) Does the region have invasive species management issues at water resources facilities, along conveyance structures, or in habitat areas?

Due to the remote nature of the region, the Inyo-Mono planning area thus far has been relatively free of aquatic invasive species. Quagga mussels have recently gained more attention in the area because of the problems they have created in nearby Lake Tahoe and the Colorado River basin. Checkpoints are set up each summer throughout the Eastern Sierra to help control the spread of this species and to educate visitors about their impacts. Thus far, however, quagga mussels have not created problems in the waterways or infrastructure of the region.

The presence of New Zealand mud snails in local fish hatcheries has limited the use of fish from infested hatcheries.

Tamarisk occurs along many natural and man-made waterways in the region and is becoming an ever-increasing threat throughout the West.

Water Demand

1) Are there major industries that require cooling/process water in the planning region?

The industrial water users in the region rely almost entirely on groundwater. Currently, there is a geothermal energy plant outside of Mammoth Lakes that pumps groundwater and moves it to their facility. They are currently looking to expand their plant and operations. There is a water bottling facility near Cartago that utilizes groundwater. Of concern to some stakeholders in the region are the many solar developments being proposed for the desert in southeast Inyo County and beyond. These facilities would require some amount of water, which would mostly be extracted from underlying aquifers. Finally, Coso Operating Company operates a wet-cooled geothermal plant in the Coso Range between Rose Valley and Coso Valley. Currently, this facility is injecting 4,800 AFY of groundwater from Rose Valley into the geothermal field to slow or reverse the depletion of fluids from the geothermal reservoir.

2) Does water use vary by more than 50% seasonally in parts of the region?

Yes. Water use in communities within the Inyo-Mono region increases substantially in the summer, primarily for landscape and air conditioning purposes. Also, water for agricultural irrigation is highly seasonal and increases in the spring and summer. Finally, water use for dust abatement on Owens dry lakebed is greatest in the winter and spring.

3) Are crops grown in the region climate sensitive?

Most of the agriculture that occurs in the Inyo-Mono region is sheep and cattle grazing. This type of agriculture will be sensitive to changes in the naturally-occurring plant community resulting from climate change. There are a few areas within the region that grow crops, such as alfalfa. These tend to be the lower-lying areas in the regions and will be vulnerable to climatic warming, altered precipitation regimes, altered snowmelt and streamflow timing, and flooding. Other types of crops occurring in the region are mostly grown on small family farms.

4) Do groundwater supplies in the region lack resiliency after drought events?

Little is known about most of the aquifers in the Inyo-Mono region, except for perhaps the Owens groundwater basin. This is a topic that needs more thorough examination throughout the region. What is known, however, is that long-term intensive pumping can lead to impacts both to the groundwater itself and to the above-ground resources.

5) Are water use curtailment measures effective in the region?

Water conservation measures have been implemented primarily in the two largest communities in the region – Mammoth Lakes and Ridgecrest. Both of the water districts serving these communities have begun water education and conservation outreach programs. While these programs have been effective so far, both are fairly new, and their long-term efficacy is yet to be seen. Other parts of the region have not yet focused heavily on water conservation. There is a perception in much of the region that because the communities are relatively high in the watershed and/or close to the source water, there is plenty of water available and conservation is not a main priority. As an indicator of the lack of attention to water conservation in the region, Inyo and Mono County residents use 3-4 times the national average of water per day.

6) Are there export demands from the region?

The City of Los Angeles has exported water from the Owens Valley and Mono Basin since 1913. These exports will continue into the future. Although the LADWP has put a substantial amount of effort into water conservation with the city of Los Angeles through retrofits, education, and restrictions, these measures will likely not decrease the demand for water exports from the Inyo-Mono region. The uncertainty and unreliability of State Water Project and Colorado River water add to the continued demand for Los Angeles Aqueduct water.

In addition to the Los Angeles Aqueduct, there is a Crystal Geyser bottling facility in Cartago. Water pumped for bottling ends up being moved out of the region, essentially creating an export of water. This facility plans to double its bottling capacity in the next few years.

Water Quality

1) Are increased wildfires a threat in

your region?

Absolutely, yes. In recent years, several fires have burned close to or even within communities in the region. As is true for much of the West, forests in the region are overgrown due to a century of fire suppression, though thinning projects have reduced the density in treatment areas. It is expected that there will continue to be larger, more intense forest fires. By the end of the century, the incidence of fire in the higher elevations of the region could increase five-to-seven-fold. While sagebrush and other desert vegetation naturally have a lower fire return interval than the region's predominant mid-elevation Jeffery pine forests, the increasing presence of humans and potential drought conditions could create higher fire hazard. Furthermore, as cheatgrass becomes more established throughout the region, we can expect an altered fire regime in high desert plant communities, including a shortened fire-return interval.

2) Does part of the region rely on surface water bodies with current or recurrent water quality issues? Are there water quality constituents potentially exacerbated by climate change?

Some streams in the region experience water quality degradation due to use by wildlife, grazing livestock, and recreationalists. This same surface water is then used by local communities or provided as export to the City of Los Angeles. Climate change may intensify the use of waterways if drought becomes more common. This is an area that needs further study for the Inyo-Mono region.

3) Are seasonal low flows decreasing for some waterbodies in the region? Are reduced low flows limiting the waterbodies' assimilative capacity?

In particularly dry years, such as 2007, some streams in the region experience very low flows. If those dry years start to stack up into multi-year drought periods, low flows could become a concern for water quality and for in-stream and terrestrial wildlife. For example, the Amargosa River, stretches of which are designated as Wild and Scenic, is currently partly ephemeral due to its desert location. Prolonged drought could impact its Wild and Scenic designation and affect the wildlife that depends on the river. Analyses of past low-flow conditions for area streams and rivers have not been done.

4) Does part of the region rely on groundwater supplies with current or recurrent water quality issues?

Yes. As described above, some of the groundwater pumped in the region exhibits naturally-occurring arsenic and/or uranium that exceed the maximum load regulations. Yet there are some wells that produce groundwater without these elements. More information is needed about the locations of arsenic and uranium contamination as well as the movement of groundwater within or among aquifers.

5) Does part of the region currently observe water quality shifts during rain events that impact treatment facility operation?

In at least two of the more densely populated communities within the region, stormwater management is a growing concern. Not only does poor stormwater management result in flooding in these communities, but it also affects the initial quality of water being treated. Increases in storm intensity and/or rain-on-snow events will exacerbate these concerns.

Flooding

1) Does critical infrastructure in the region lie within a 200-year floodplain?

Two hundred-year floodplain data are not available for the Inyo-Mono region. Instead, 100-year floodplain data were used. The vulnerable areas include the upper East and West Walker River Watersheds, parts of the Owens Valley, the Tri-Valley, and some of the inter-mountain valleys in southeast Inyo County, particularly those in Death Valley National Park. There is critical water conveyance and water storage infrastructure in the Walker, Owens, and Tri-Valley areas.

2) Does aging critical flood protection infrastructure exist in your region?

Yes. Where there is flood protection infrastructure, much of it is aging and in need of repair or replacement. For example, the diversion ditches and gates in the Antelope Valley (West Walker Watershed) are old and were damaged by a recent flood, rendering them virtually non-operational.

3) Have flood control facilities been insufficient in the past?

Yes. Refer to the example of the Antelope Valley above. The bigger issue, however, is lack of flood mitigation programs in much of the region.

4) Are wildfires a concern in parts of the region?

Yes. This hazard is discussed above. The loss of vegetation caused by wildfires has led recently to intensified erosion and flooding, impacting habitat, fisheries, and communities.

Terrestrial and Aquatic Ecosystems

1) Does the region include aquatic habitats vulnerable to erosion and sedimentation issues?

Yes. Because of the complex topography of the region and the numerous large and small waterways, erosion is an ongoing occurrence. However, erosion exacerbated by wildfires or extreme precipitation events can lead to increased water quality concerns and degraded in-stream habitat.

2) Does the region include estuarine habitats which rely on seasonal freshwater flow patterns?

There are no estuaries in the Inyo-Mono region as there is no connection to the ocean. All of the region lies inland.

3) Do climate-sensitive flora or fauna live in the region?

All plant and animal species are sensitive to climate in some way. Some species have larger tolerances (or climate envelopes) than others. Some species, such as sagebrush, saltbush, some tree and bird species, deer, and mountain lions are able to tolerate the large diurnal and seasonal fluctuations in temperature and precipitation in the region. Other species, particularly those that live at the highest elevations in the region, are more specialized and thus may be impacted disproportionately by climatic changes. Terrestrial species including pika, mountain yellow-legged frog, willow flycatchers, desert tortoise, and desert bighorn sheep have been garnering increased attention due to climate change, while pupfish and hydrobiid snails are examples of aquatic species that show sensitivities to climate-driven habitat changes.

4) Do endangered or threatened species exist in the region?

Yes. There are endangered and threatened plant and animal species in the region, some of which occur only within this region. A full list specific to this effort has not yet been developed.

5) Are changes in species distribution already being observed in parts of the region?

Again, high-elevation species with limited habitat and smaller climatic tolerances seem to be moving to more favorable habitat (or are running out of favorable habitat). Most evidence of species movements in the region thus far has been anecdotal. More quantitative observations are needed.

6) Does the region rely on aquatic or water-dependent habitats for recreation or other economic activities?

Absolutely, yes. Tourism drives the economies of virtually every community within the region except Ridgecrest. In the winter, tourism is largely snow-based and includes skiing and snowmobiling, both of which are fully dependent on winter snowfall. Summer recreation revolves mostly around watersports – fishing, boating, etc. Several fish spawning and rearing facilities operate in the region and rely on water from natural streamflow. It could be argued that most jobs in the region can be related to the central position of water in the region's economy.

7) Are there rivers with quantified environmental flow requirements or known water quality/quantity stressors to aquatic life?

Yes. There are now quantitative environmental flow requirements for several waterways in the Inyo-Mono region, including Mono Lake tributaries, Mammoth Creek, and the lower Owens River. Some of these requirements are currently under discussion, and it is unknown whether climate change is being considered as a potentially complicating factor.

8) Do other sensitive habitats occur in the region?

Yes. Meadows and other wetland-type habitat occur at both the higher and lower elevations of the region. These habitats are dependent on unimpeded seasonal water availability and support a large number of species.

9) Does the region include one or more of the habitats described in the Endangered Species Coalition's Top 10 habitats vulnerable to climate change?

Yes. The Inyo-Mono region includes two of these habitats: the Sierra Nevada and the Southwest deserts. In addition, one of the Endangered Species Coalition's other ecosystems of focus is the sagebrush steppe.

10) Are there areas of fragmented habitat in the region? Are there movement corridors for species to naturally migrate? Are there infrastructure projects planned that might preclude species movement?

Fortunately for wildlife, much of the land in the Inyo-Mono region is undeveloped. Because much of the land area is owned and managed by federal or local resource agencies, threats to wildlife coming from development are relatively few, and species are able to move relatively freely throughout the region and into adjacent regions. There are some more localized examples of fragmented habitat, such as that occurring from groundwater pumping in the Owens Valley. Meadows and wetlands seem to be particularly vulnerable to fragmentation in the region because they occur in otherwise development-friendly areas. While large-scale infrastructure is not typically a problem in the Inyo-Mono region, the proposed large solar developments in southeast Inyo County have become a growing concern. Not only would these developments alter habitat quality, but they could also create barriers to species movement, such as for the desert tortoise.

Table 3-1. Summary of climate change impacts and vulnerabilities in the Inyo-Mono region by category.

Category	Impacts	Vulnerabilities
Water Supply	• Changes in amount of snowpack, SWE • Timing of snowmelt, runoff and streamflow • Increased rain-on-snow events • Extreme precipitation events • More rain, less snow • Groundwater recharge	• Snowpack • Storage capacity • Drought tolerance
Water Demand	• Longer, drier summers • Increase in summer water demand • Increased demand from City of L.A.	• Solar energy developments • Agriculture • Landscape irrigation • City of Los Angeles • Water conservation
Water Quality	• Intensified summer recreation • Longer grazing seasons • Unknown impacts to groundwater quality	• Wildfires • Erosion • Stormwater/flooding • Recreation • Seasonal low flows • Groundwater contaminants
Flooding	• Increased rain-on-snow events • Extreme precipitation events • Increased wildfire incidence • Unknown impacts of altered snowpack, snowmelt, and streamflow	• Lack of, inadequate, or aging infrastructure • Wildfires

Category	Impacts	Vulnerabilities
Terrestrial and Aquatic Ecosystems	• Changes to species distributions • Novel and unpredictable species relationships and interactions • Competitive advantage of invasive species • Hydrological impacts – changes to water temperature, pH, DO, turbidity, and flow regimes	• Aquatic habitats • Meadows, wetlands, estuaries • Climate sensitive species • Threatened and endangered species • Species distributions • Reliance on aquatic ecosystems for recreation and livelihoods • In-stream environmental flow requirements

Prioritizing Vulnerabilities

New to this update of the Phase II Plan is a list of prioritized climate change vulnerabilities specific to the Inyo-Mono region. An overarching theme that is common to all vulnerabilities is the lack of region-specific information and an underdeveloped understanding of potential impacts to the region. Therefore, the highest priority for data gathering related to climate change (see next section) is simply collecting and/or developing more region-specific information. The prioritized vulnerabilities presented below follow from the vulnerability analysis in the previous section but do not always match the specific topic within the specific category (e.g., see discussion of groundwater, below). Furthermore, not all of the vulnerabilities discussed in the analysis are listed below. These are simply the most important vulnerabilities for the region at this time. The importance of vulnerabilities is expected to change over time.

Priority vulnerability #1: Snowpack and snowmelt. Because we depend so entirely on the winter snowpack and spring snowmelt for our surface water supplies and to recharge the lower-elevation groundwater basins, improving our understanding of potential changes to these processes is our first priority. We need more regional-scale climatic and hydrologic modeling results available for our region. This information would also help us understand how rivers with regulatory flow requirements might be impacted by altered hyrology.

Priority vulnerability #2: Groundwater quantity and quality. The level of understanding of most of the 61 groundwater basins in the region is very low. For most basins, we lack knowledge of how groundwater levels fluctuate naturally over time; how human and agricultural water use impacts the amount and quality of groundwater; where and how much recharge occurs each year; and what impacts the quality of groundwater. While CASGEM measurements will improve our knowledge about our groundwater basins, these measurements will likely be concentrated in the most highly-populated areas, thereby exacerbating the dearth of information in less-used basins.

Priority vulnerability #3: Water quality. There have been no reported studies that we know of that either model or measure the impacts of climate change on water quality, such as through changes in runoff, changes in seasonal low flows, changes in water use/demand, or increased number or frequency of extreme events. Similar to water supply, we need to understand changes to water quality on a regional level in order to advise land and water managers and to inform planning.

Priority vulnerability #4: Water demand. The seasonal variation in water demand throughout the region is concerning. Although there has been more talk of water conservation in recent years due to drought conditions, not enough conservation is taking place. Although the California governor requested a drop in water usage statewide by 20% as of early 2014, actual water use has fluctuated between a 5% decrease and a 5% increase. Water conservation needs to become a way of life, however, and not just in drought periods. We need improved knowledge of and education about our water sources, our water use, and how we, as individuals, can impact overall water demand. It is time to sound the alarm, particularly at the local level. A complicating factor in water demand in the Inyo-Mono region is the ongoing export of water to Los Angeles. There is a viewpoint of some residents in the Inyo-Mono region that any water conserved in the region "just goes to L.A.", and therefore we should not conserve.

Priority vulnerability #5: Flooding. As we expect to see increases in extreme weather events – in number and/or frequency, we would expect to experience more flooding in the region. Yet there is still a lack of understanding in how extreme events might change into the future, particularly at the regional level. Flooding is also a concern in the area because of the aging flood/stormwater control infrastructure, some of which is already insufficient to handle the largest floods. Flooding that occurred in several parts of the region over the last decade may provide a glimpse into the future. We could also use updated and improved floodplain maps for the region. Several tribes, in particular, have expressed concern that existing floodplain maps do not accurately represent the reality of flooding on the reservations.

Priority vulnerability #6: Waterways as drivers of the economy. Water drives so many parts of the economy in the region: recreation-based tourism (skiing, snowmobiling, fishing, boating, sightseeing), education (about communities, water resources, and ecosystems), and agriculture (crops, livestock grazing, hatcheries). More work is needed to understand and quantify likely impacts of climate change on these sectors. Significant negative impacts to any one aspect of the regional economy would likely damage livelihoods and result in population shifts away from the region.

Priority vulnerability #7: Water-dependent ecosystems. Similar to many of the other types of impacts expected in the Inyo-Mono region, impacts to water-dependent ecosystems are only broadly understood at this point. More information is needed on impacts to both individual species and to communities and ecosystems. Threatened and endangered species' responses to climate change are a particularly needed area of study.

Priority vulnerability #8: Wildland and structural fire. Each year, fire becomes a more imminent concern for communities in the Inyo-Mono region. In the last decade, several fires have burned adjacent to or even within communities. Increasing drought conditions and longer, drier summers will heighten the fire risk in the region. More quantified, region-specific information regarding possible changes in fire frequency and intensity would be helpful. Indeed, fire may soon move up the list of priority vulnerabilities.

Plan for Data Gathering and Analysis for Vulnerabilities

Although we know that climate change portends significant impacts for many parts of the water management system in the Inyo-Mono region, climate change "projects", per se, are not high priority actions for Inyo-Mono stakeholders. Instead, projects examining particular aspects of climate change, such as drought impacts or water demand, will gain more traction among regional water managers. As we saw in the prioritized list of vulnerabilities above, we need improved and more quantified information about virtually every kind of impact expected, including the climatic changes themselves.

While individual water systems and stakeholders will continue to work on behalf of their communities and water resources, the IRWM Program can act as an organizer of larger climate change-related projects. There is little internal funding available within regional stakeholders for data gathering and analysis; most of these activities would be dependent upon external grant funding. As a region with a large number of economically-disadvantaged communities and small population, we also have limited resources for seeking out and applying for such funding. For example, there is currently no opportunity to pay for grantwriters to apply for grant funding. For most climate change information gathering-type projects, Program Office staff would need to work on grant applications as volunteers, or IRWM stakeholders would need to take on grantwriting tasks as additional duties in their already busy jobs.

Despite those limitations, however, we do have some immediate priorities for climate change analysis that would greatly benefit the region. The biggest immediate need is for some more quantitative hydrologic trend information. We have already begun to look for opportunities to partner with entities that do hydrologic modeling and would be willing to use such models for the Inyo-Mono region. Having this kind of quantitative model output would go a long way in helping us identify and measure potential impacts to the water management system. Another high priority is to implement more surface water and groundwater monitoring throughout the region so that we can spot changes as they occur and begin to develop long-term datasets. Some of these types of measurements are already underway by IRWM stakeholders; the IRWM Program can work to ensure that this information is collected on a truly region-wide basis, but again, funding is needed and is difficult to come by. The IRWM Program will work to take on climate change-related activities in partnership with regional stakeholders as time and funding allows and will do its best to seek out funding opportunities for specific data gathering and analysis priorities.

Measuring Impacts of Climate Change for the Inyo-Mono Region

After assessing which water-related resources in the Inyo-Mono region are vulnerable to the impacts of climate change, it is important to attempt to understand to what degree these resources will be impacted. A full quantitative impacts analysis for these resources (water supply, water demand, water quality, flooding, terrestrial and aquatic ecosystems) is beyond the scope of this iteration of the Inyo-Mono IRWM Plan; instead, a brief qualitative assessment of likely impacts is provided in the previous section. Future updates of the Inyo-Mono Plan will incorporate regional data to allow for more robust and quantitative impact analyses for each of these resources. In order to understand potential impacts of climate change, however, it is important to first consider what changes in the climate might be expected.

Changes in the Climate

As discussed at the beginning of this chapter, the most currently-accepted means of understanding possible future climatic patterns is through computer models. Because different models have different strengths and weaknesses, many climate change practitioners have taken to using a suite or "ensemble" of models to develop an average and range of projected future conditions. A 2009 study commissioned by the California Climate Action Team (CAT), a group of state government officials working to implement greenhouse gas emissions reductions programs as well as the state's Climate Adaptation Strategy, used six GCMs to drive subsequent impact analyses (DWR 2010). These GCMs were selected based on their ability to model historical precipitation and temperature patterns and variability, as well as the El Niño Southern Oscillation, and are listed below.

Table 3-2. General circulation models used by Climate Action Team and Inyo-Mono RWMG

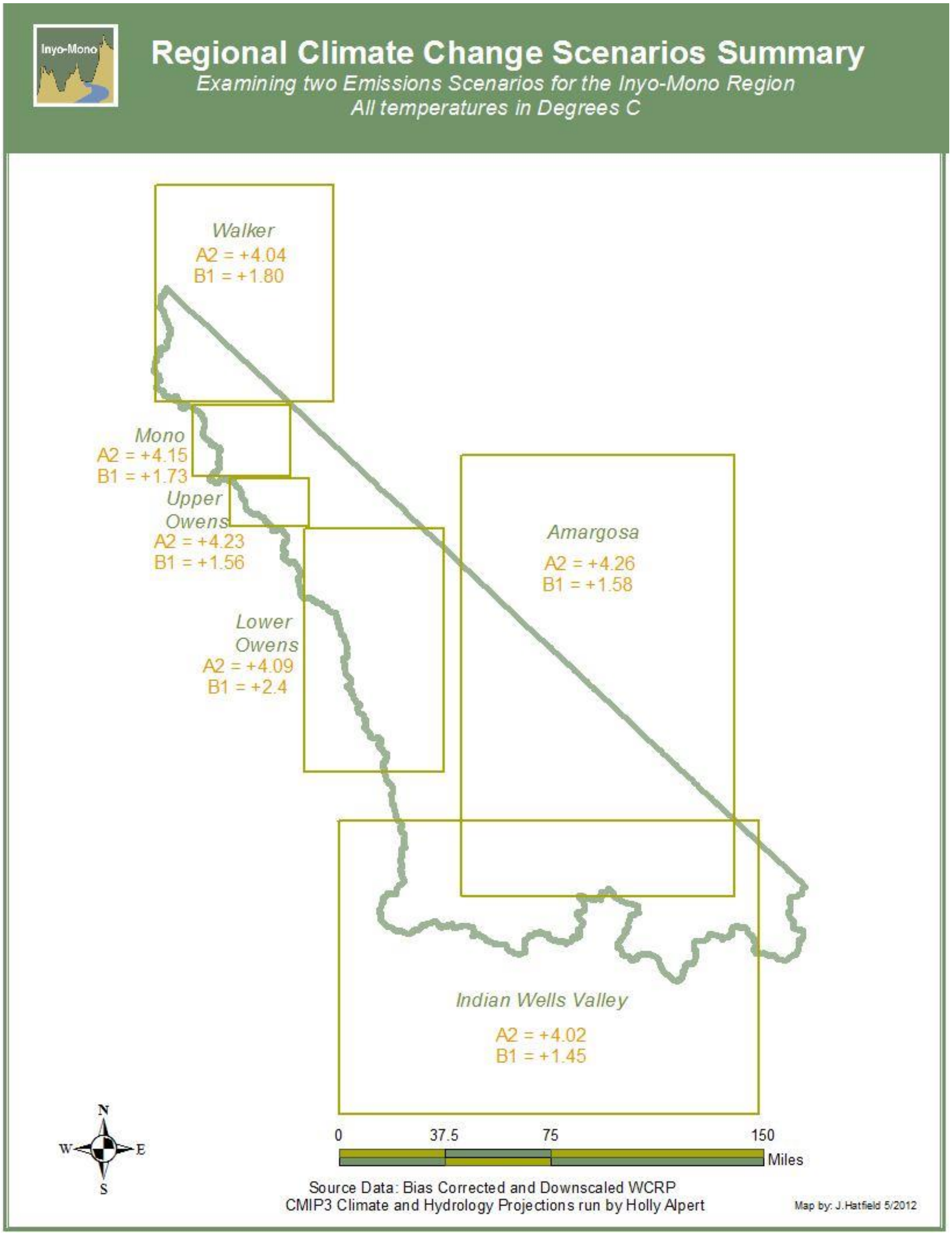
No.	Model name; modeling group, country	Model identification	Primary reference year
1	Parallel Climate Model; National Center for Atmospheric Research (NCAR), USA	PCM	2000
2	Geophysical Dynamics Laboratory model version 2.1; US Dept. of Commerce / National Oceanic and Atmospheric Administration (NOAA) / Geophysical Fluid Dynamics Laboratory (GFDL), USA	GFDL-CM2.1	2006
3	Community Climate System Model; National Center for Atmospheric Research (NCAR), USA	CCSM3	2006
4	Max Planck Institute (MPI) for Meteorology, Germany	ECHAM5/ MPI-OM	2006
5	Center for Climate System Research (University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC), Japan	MIROC3.2 (medres)	2004
6	Meteo-France / Centre National de Recherches Meteorologiques (CNRM), France	CNRM-CM3	2005

A collaboration of research institutions and federal agencies has made these models, along with others, readily available through the World Climate Research Programme's (WRCP's) Coupled Model Intercomparison Project Phase 3 (CMIP3) model output archive (http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html#Welcome). Through the archive's website, the user can request biased-corrected spatial downscaled (BCSD) model output for any geographic region and for any time period within the 21st century. Both temperature and precipitation projections are available. This set of projections has been widely reviewed and used by scientists and practitioners in California. Models can be run with any combination of three IPCC Special Report on Emissions Scenarios (SRES) – A1B, A2, or B1. These emissions scenarios represent a set of "best guesses" of what future emissions might be based on population, economic conditions, energy sources, technological development, environmental policy, etc. A1B is a medium-emissions scenario, reaching approximately 700 ppm CO_2 by 2100 (global CO_2 is currently appx. 390 ppm). B1 is a lower-emissions scenario, leveling out at just over 500 ppm by 2100, while A2 is a higher-emissions scenario and reaches 850 ppm by 2100.

The same six GCMs listed in Table 3-2 were used for an analysis of project climatic changes for the Inyo-Mono region for the 21st century, using the downscaling method described in the previous paragraph. Only the A2 and B1 emissions scenarios were used, in order to bound the high and low probabilities of changes in the atmosphere. Six geographic areas within the region were chosen, based on watersheds and/or areas where most of the population resides. Because the model output is only available on a grid scale, it was not possible to request projections for true watersheds. Table 3-3 lists the approximate watersheds for which projections were downloaded, and Figure 3-2 shows the geographic extent.

For each region, projections of temperature and precipitation were examined through the 21st century. For each year, average temperature was calculated for the output of the six models and each of the two emissions scenarios. In addition, the highest temperature value and lowest temperature value were identified in an attempt to elucidate the range of possible temperature scenarios. Similarly, cumulative precipitation was calculated for each year based on the model output and two emissions scenarios. An average was calculated over the six models and then a highest precipitation value and lowest precipitation value were identified in order to acknowledge the uncertainty in the projections and the range of possibilities.

Figure 3-2. Geographic area for each downscaled climate model analysis.



Below, graphs are presented for each watershed/area of interest. The top graph in each geographic region is for temperature and shows the mean value of average annual temperature as well as the highest value and lowest value for the two emissions scenarios. For both emissions scenarios, temperature is expected to increase over the next century, though less so under the B1 scenario. The bottom graph shows precipitation over the next century based on projected average cumulative precipitation for both emissions scenarios as well as the highest value and lowest value as explained above. For all areas analyzed, there is no discernible trend in precipitation amounts through 2100. This result matches with literature cited at the beginning of this chapter stating that model projections of future precipitation patterns are inconsistent.

Figure 3-3. Temperature Projections for Amargosa Basin

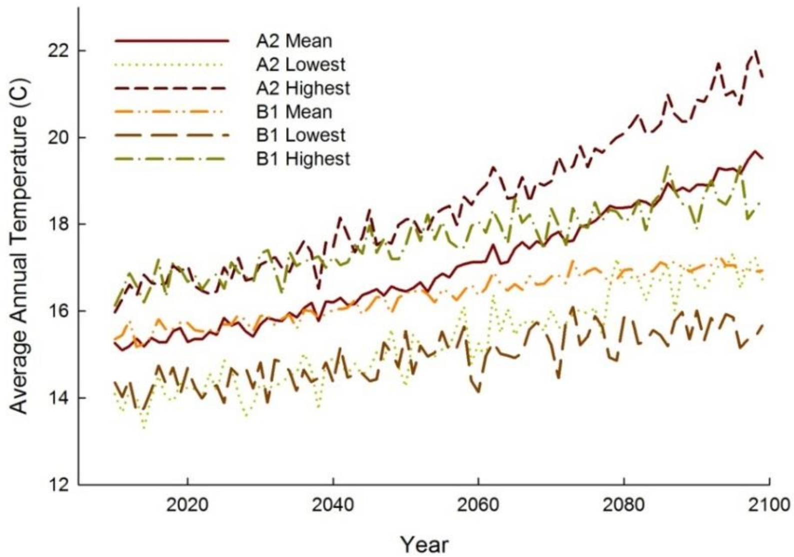


Figure 3-4. Precipitation Projections for Amargosa Basin

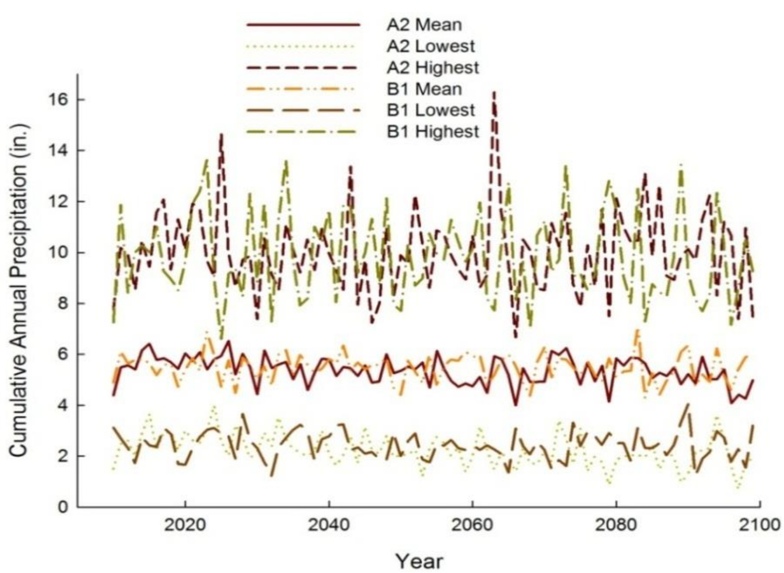


Figure 3-5. Temperature Projections for the Indian Wells Valley

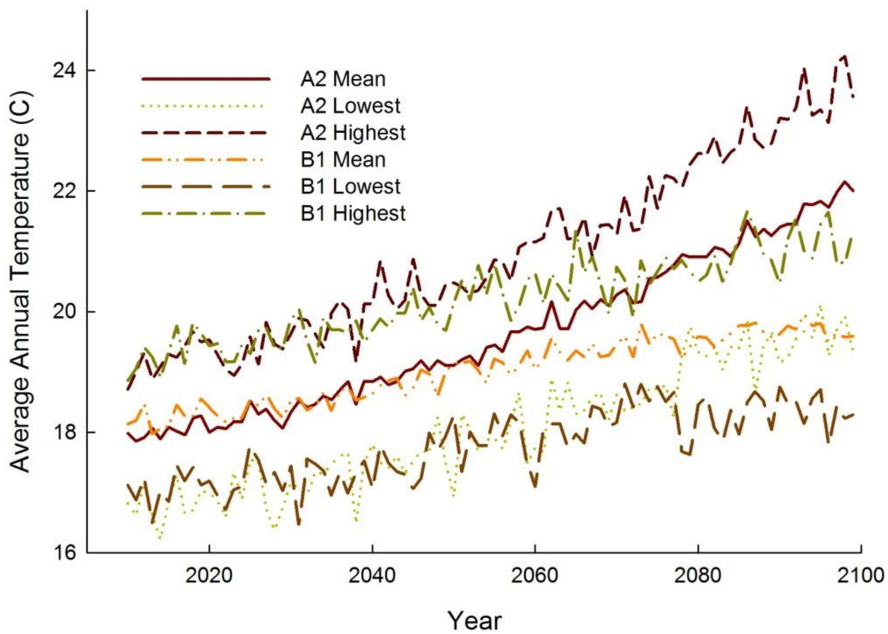


Figure 3-6. Precipitation Projections for Indian Wells Valley

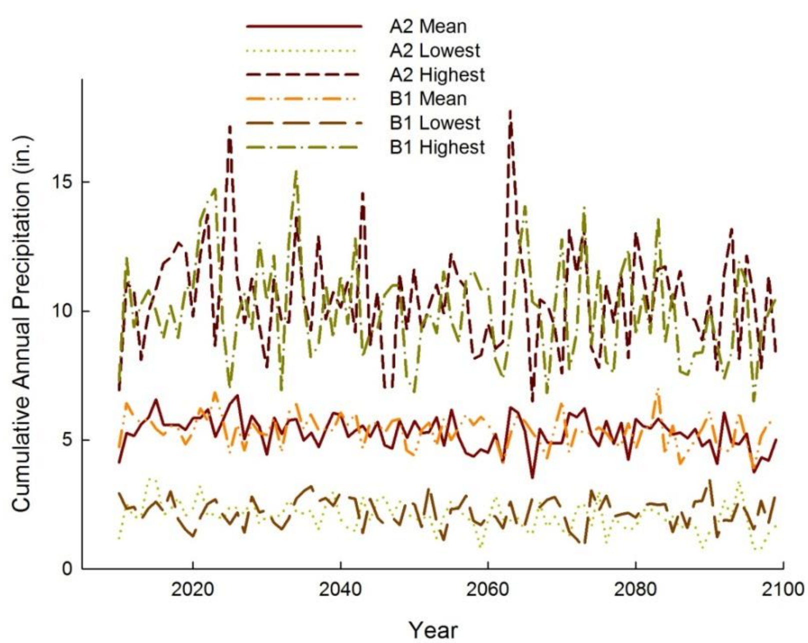


Figure 3-7. Temperature Projections for the Lower Owens River

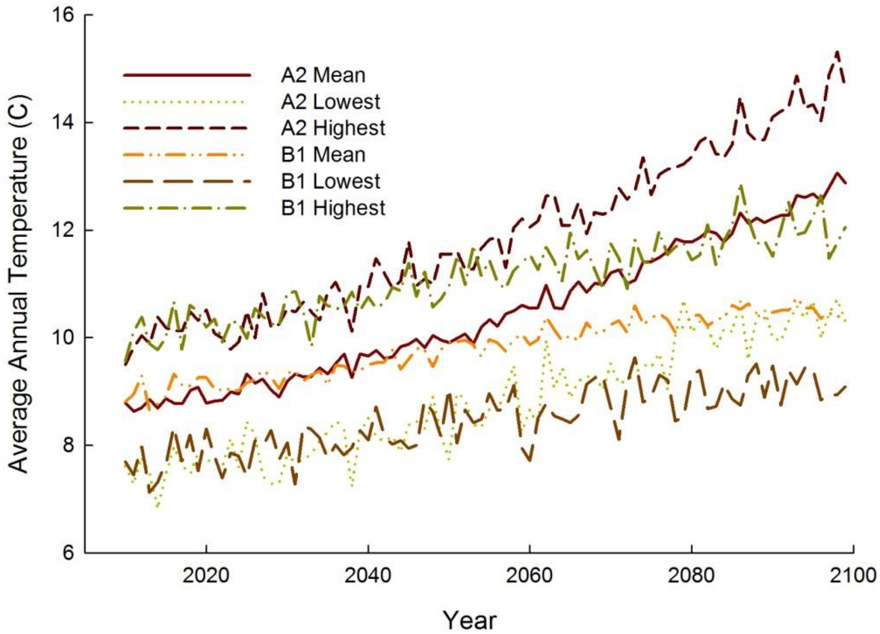


Figure 3-8. Precipitation Projections for Lower Owens River

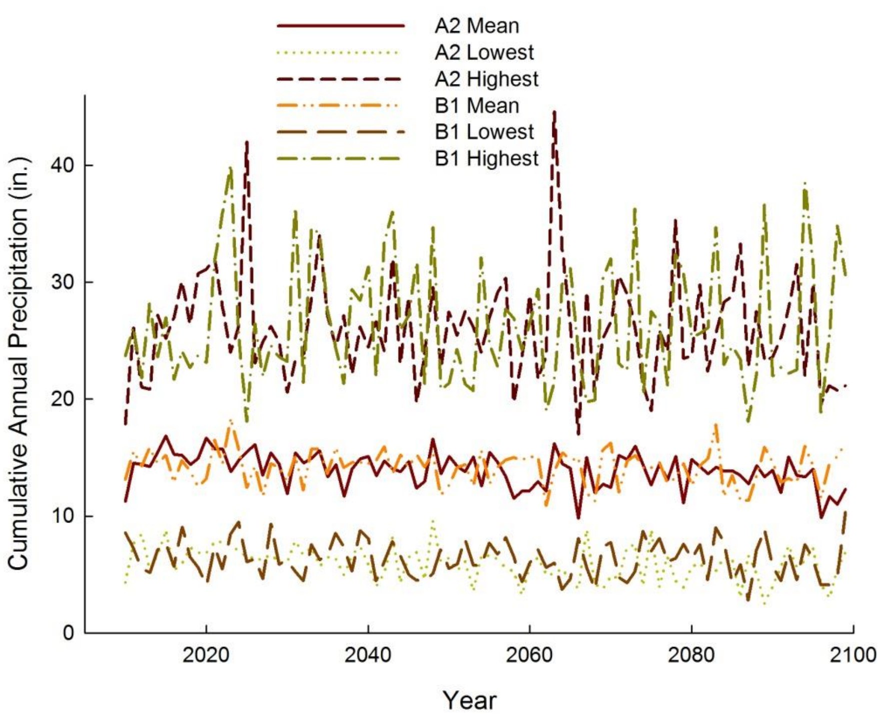


Figure 3-9. Temperature Projections for the Upper Owens River

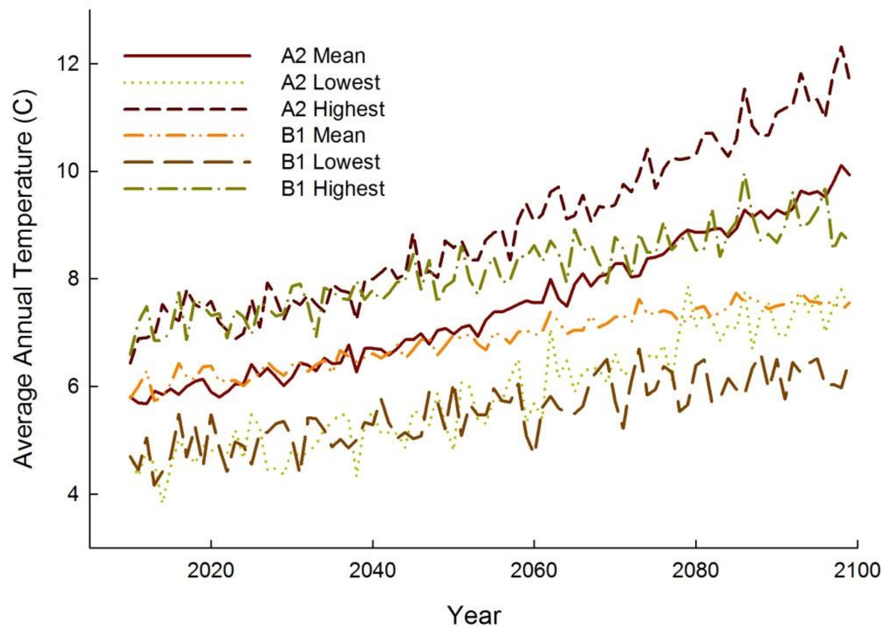


Figure 3-10. Precipitation Projections for Upper Owens River

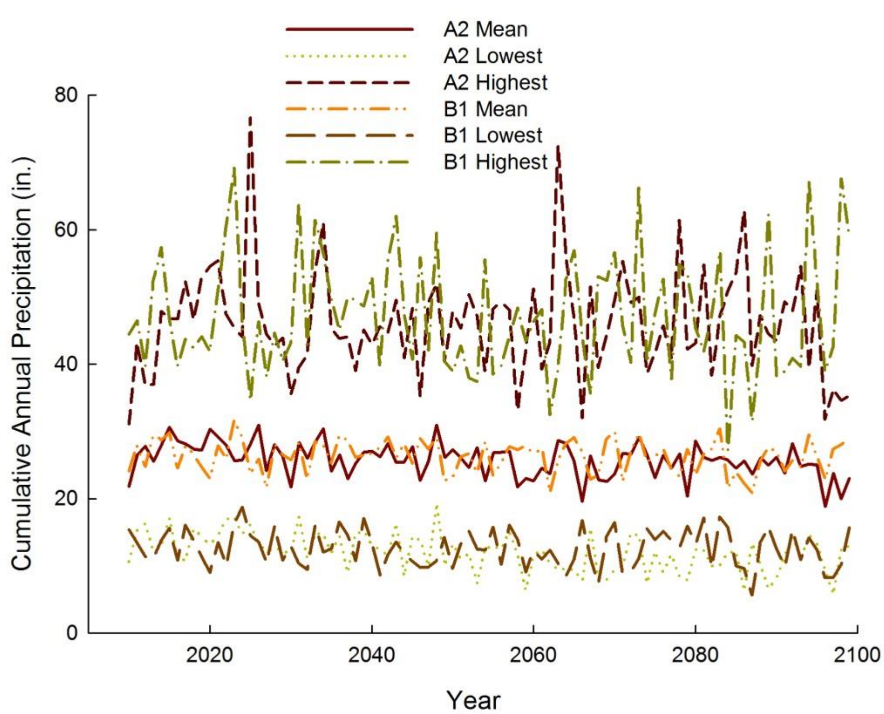


Figure 3-11. Temperature Projections for the Mono Basin

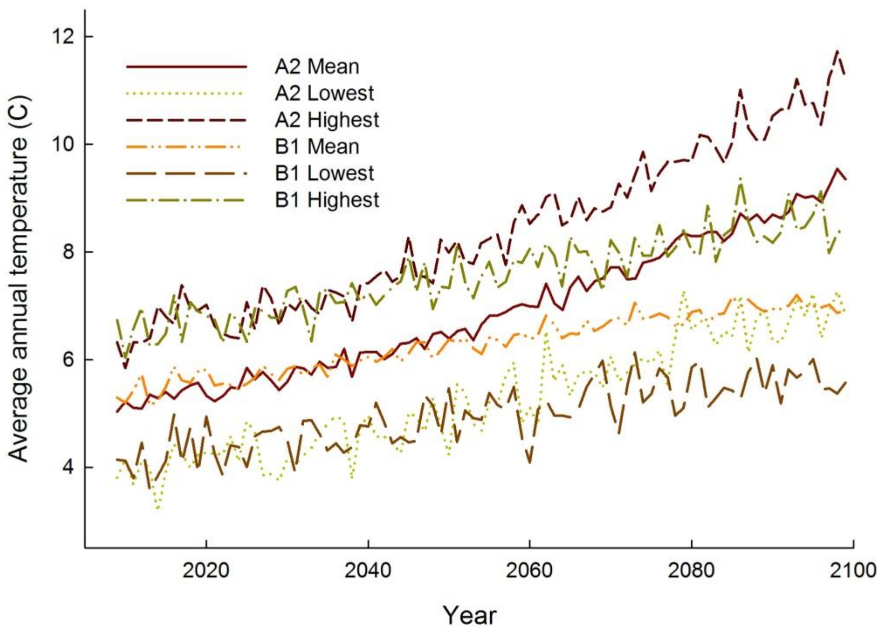


Figure 3-12. Precipitation Projections for the Mono Basin

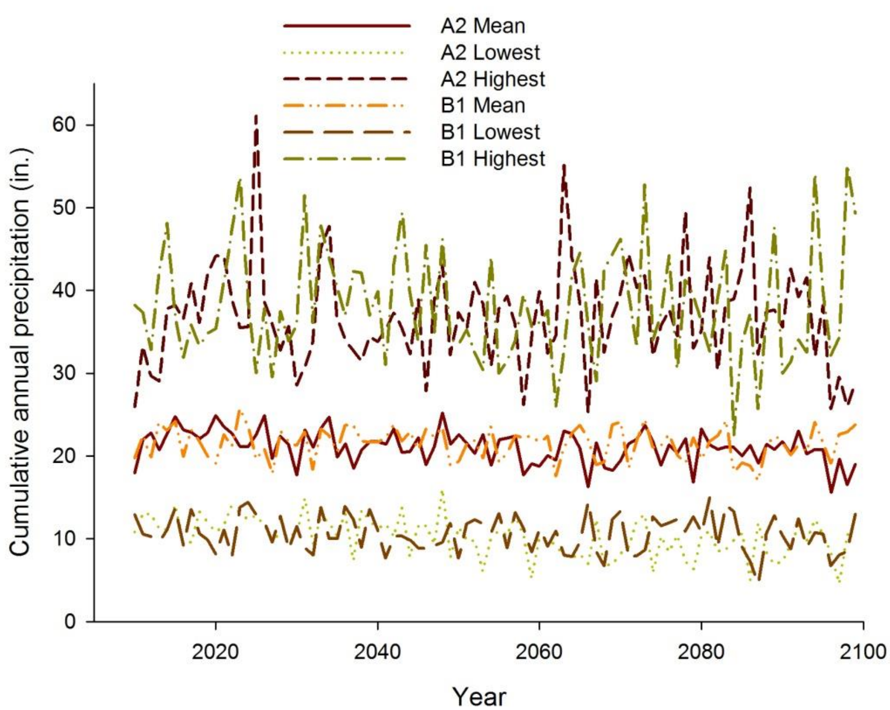


Figure 3-13. Temperature Projections for the East-West Walker

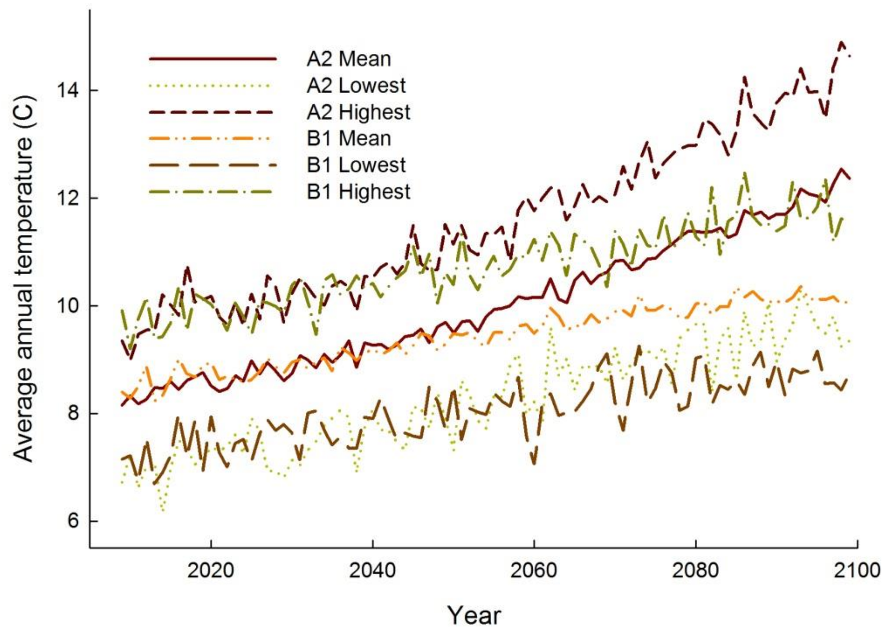
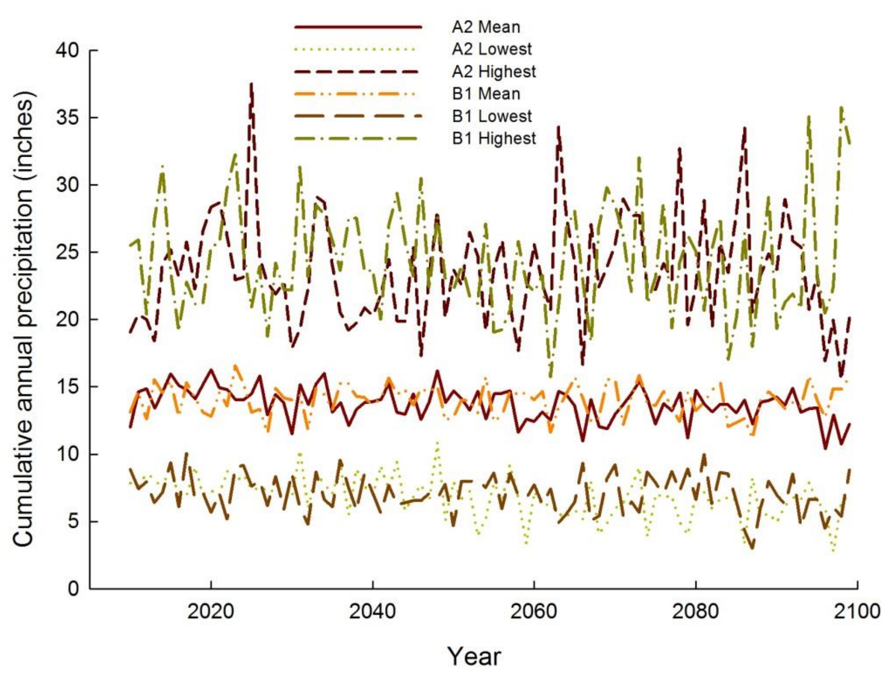


Figure 3-14: Precipitation Projections for the East-West Walker



Future Analysis for the Inyo-Mono Region

Although a substantial amount of work has been done to understand the impacts of climate change to the Sierra Nevada snowpack and streamflow, much of this work has been focused on western Sierra watersheds because of their importance to the Bay-Delta system and urban water supplies. Relatively little analysis has been performed on eastern Sierra hydrology, despite the importance of our waterways not only for local communities and in-stream uses, but for water exports to Los Angeles and urban uses. The analysis of climate change projections presented above is a first step to understanding possible changes to snowpack and streamflow in the Inyo-Mono region; the next step is to incorporate these climate projections into models of streamflow in order to try to understand more directly impacts to water supplies, water quality, and ecosystem health. While streamflow modeling is beyond the scope of this iteration of the Inyo-Mono IRWM Plan, it will be pursued by the RWMG as a part of upcoming work on climate change as a way to better understand climate change impacts to the region, and results will be incorporated into a future version of the Plan. In the meantime, we will use the best available science to provide information to water resource managers and practitioners as they prepare to deal with and respond to climate change.

Climate Change Adaptation Strategies for the Inyo-Mono Region

In the context of climate change, *adaptation* is defined as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects" (http://climatechange.worldbank.org/climatechange/content/adaptation-guidance-notes-key-words-and-definitions). Climate change adaptation strategies as they relate to water resources management have gained increasing attention and momentum over the last decade. Researchers and state and federal agency officials have put much thought into the subject and have produced a plethora of reports, papers, and guidance. While examples of adaptation practices are increasing, published case studies are still lacking. DWR published a report in 2008 titled "Managing and Uncertain Future: Climate Change Adaptation Strategies for California's Water". In this report, DWR proposes 10 adaptation strategies for water resources management (DWR 2008):

1) **Provide sustainable funding for statewide and integrated regional water management**
2) **Fully develop the potential of integrated regional water management**
3) **Aggressively increase water use efficiency**
4) **Practice and promote integrated flood management**
5) **Enhance and sustain ecosystems**
6) **Expand water storage and conjunctive management of surface and groundwater resources**
7) **Fix Delta water supply, quality, and ecosystem conditions**
8) **Preserve, upgrade, and increase monitoring, data analysis, and management**
9) **Plan for and adapt to sea level rise**
10) **Identify and fund focused climate change impacts and adaptation research and analysis**

While not all of these strategies are relevant for the Inyo-Mono region, many of them are, and using this list as a guide will allow water managers to begin thinking about how to manage their water supplies in response to climate change impacts. Below is a consideration of the most relevant of the DWR adaptation strategies for the Inyo-Mono region.

1) **Provide sustainable funding for statewide and integrated regional water management**
2) **Fully develop the potential of integrated regional water management**

These first two adaptation strategies are closely related. While the first strategy is extremely pertinent for, and is strongly supported by, the Inyo-Mono planning region, it is not within direct control of the region. The Inyo-Mono RWMG is committed to maintaining a long-term presence in the region and will continue to build its program, including finding funding opportunities for high-priority projects as well as bringing other needed resources to the region. In addition, the RWMG will continue its involvement in statewide water fora so as to have a voice in determining management and funding priorities.

3) **Aggressively increase water use efficiency**

Awareness of water conservation has increased throughout the region over the past several years, as have water conservation practices. These measures have included encouraging water-efficient and native landscaping, installing water meters, and educating water consumers about efficient landscape irrigation. Regardless of climate, all communities within the region can benefit from increasing water use efficiency. Furthermore, those water districts that have successfully implemented water conservation measures can serve as a resource for smaller districts that have yet to implement programs.

4) **Practice and promote integrated flood management**

It has become more apparent to the RWMG that flood management is a common issue shared by several areas in the region. Integrated flood management does not take on the same meaning in the Inyo-Mono region as it does in other parts of California, such as the Central Valley. However, because of the large amount of undeveloped and public land in the region, managing the land use-water use nexus requires a great deal of thought and collaborative planning. More careful planning around flood management needs to take place, and such planning will help land and water managers address climate change impacts such as rain-on-snow events, increased wildfire incidence, and earlier peak streamflow.

5) **Enhance and sustain ecosystems**

Many organizations and individuals are working in the Inyo-Mono region to enhance and sustain ecosystems. The Inyo-Mono RWMG has adopted an objective related to ecosystem stewardship and has committed to promoting projects that would help meet this objective.

6) **Expand water storage and conjunctive management of surface and groundwater resources**

This adaptation strategy represents perhaps one of the most significant opportunities within the Inyo-Mono region. In certain parts of the region, groundwater resources have been thoroughly monitored over time (see Chapter 4: Data Management and Technology for more information).

In other areas, the recent implementation of the CASGEM program will help to ensure more accurate information on groundwater basins. In general, however, opportunities for aquifer recharge and storage have not been thoroughly explored.

8) Preserve, upgrade, and increase monitoring, data analysis, and management

This adaptation strategy represents another large opportunity for the Inyo-Mono region. Again, while some geographical and topical areas within the region have been well explored, others have received little attention. The RWMG has been working with individual entities in the region to identify their data collection and data management efforts, and a summary of the findings is provided in the Data Management chapter. The RWMG, through its data management program, can help identify the gaps in monitoring and data, and develop plans and identify resource for filling those gaps.

10) Identify and fund focused climate change impacts and adaptation research and analysis

Over time, the RWMG will identify climate change-specific projects and seek out funding opportunities. An alternative may be that projects focus on a different issue but have a benefit related to climate change adaptation. In a region where basic water supply and water quality issues are of utmost concern to the residents, climate change simply is not at the forefront of water managers' thinking. However, it is possible that climate change impacts and adaptation strategies can be incorporated into our thinking about water management and planning simply as an extension of our current ways of thinking.

Climate Change Mitigation

In contrast to adaptation, which consists of actions that respond to the impacts of climate change, climate change mitigation refers to strategies to reduce the causes of climate change, such as limiting the amount of greenhouse gases being emitted. Recently, increasing attention has been paid to reducing the amount of energy used in water resources management. The nexus of energy and water is increasingly identified as having large potential for greenhouse gas (GHG) mitigation. In California, 19% of the state's electricity and 30% of the state's non-power plant natural gas is used for conveyance, treatment, distribution, and end use of water (Climate Action Team 2008). This statewide baseline assessment is very important because identifying the largest sources of water-related emissions helps to prioritize projects by taking into account the potential emissions reduction, which often corresponds closely to cost savings, thus creating a more accurate cost-benefit analysis. Conducting a similar analysis on the IRWM region scale will ideally improve project prioritization and cost savings for the Inyo-Mono region.

In the Inyo-Mono region, little to no accounting of water-related energy use and greenhouse gas emissions has taken place. While techniques to perform such accounting have improved, most water agencies and rural water districts in the region do not have the resources to perform these tasks. In partnership with the Sierra Nevada Alliance, we have begun performing initial assessments of energy use and emissions for the larger water districts within the region: Mammoth Community Water District, Indian Wells Valley Water District, and June Lake Public Utilities District. It is the intention that by performing emissions inventories for the larger districts first, the methodologies can be worked out, and this experience will make it easier to then communicate with the numerous small community services districts, mutual water companies, and the like, in order to perform individual emissions inventories. Two further inventories were completed through the disadvantaged communities grant. The results of those assessments will be included in a future update of the Plan.

The IRWM Plan standards require that a process be created to consider GHG emissions when choosing between project alternatives. At this time, the IRWM Program has neither the financial resources nor the authority to demand that emissions inventories be performed outside of the IRWM process by potential project proponents. However, as much as project proponents are required to perform CEQA analysis of various project alternatives, they will be required to consider GHG emissions for each alternative, and this information can then be used in the IRWM project review process. We will also encourage RWMG Members with more resources (such as the urban water suppliers) to assist in such analysis for Members with fewer resources. If funding allows, we would consider working with an outside entity, such as the Sierra Nevada Alliance, that has the expertise and established methodology for assessing GHG emissions.

GHG Inventory Methodology

Boundaries and Sources

The initial GHG inventory for the Inyo-Mono region focuses on the larger water utilities within the region, partly because of the availability of information within these agencies, and partly because of their larger energy use compared to smaller water districts and individual wells and septic systems. Once the emissions inventory protocol is established, future inventories will be easier to conduct, particularly for smaller water purveyors that may not have data readily accessible.

Table 3-4 shows the potential GHG emission sources relevant to water utilities. Direct emissions are those emitted by activities within the region itself (i.e. motor vehicles) while indirect emissions are emitted outside of the region, but are due to activity in the region (i.e. electricity generation). Notice wastewater is included in both categories because the utility may have onsite treatment or may send its wastewater to another site for treatment. Direct and indirect emissions are commonly referred to as Scope 1 and Scope 2 emissions, respectively. There is a Scope 3 that includes activities such as workers' commutes and emissions from the manufacture of goods used by the region (lifecycle emissions), but these are not included in this inventory.

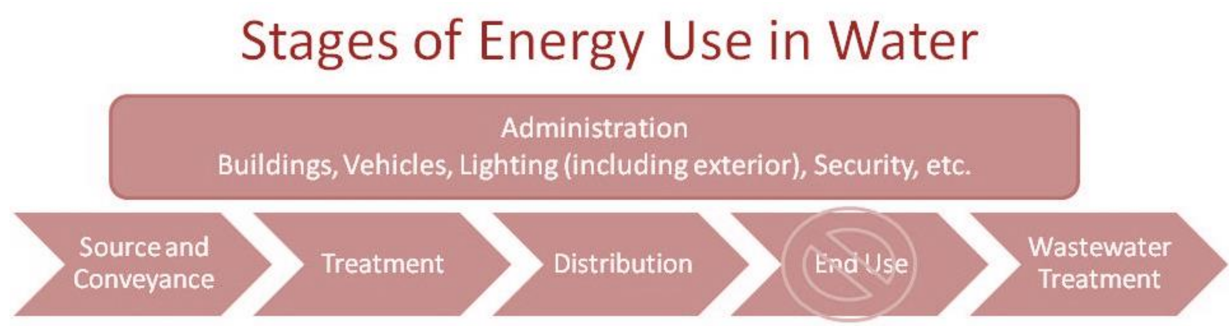
Table 3-3. Direct and indirect water-related emission sources

Emissions Type	Source Sector	Source Category
Direct (Scope 1)	Transportation	On-road mobile sources (motor vehicles: passenger cars, trucks, buses)
		Off-road vehicles (boats, snowmobiles, lawn and garden equipment, etc.)

	Fuel combustion	Natural gas combustion (residential and commercial)
		Other fuel combustion (propane, wood, etc.)
	Waste	Wastewater treatment
Indirect (Scope 2)	Energy	Electricity consumption
		Wastewater treatment

When discussing the energy-water nexus, it is important to identify which steps of the water use process produce the most emissions. Those steps with the most emissions are often the most costly, due to energy prices. Figure 3-2 shows the different stages of water-related energy use. This inventory does not look at the end user (i.e. water heating), although that may be possible to calculate in future inventories using resources such as the Residential Energy Consumption Survey.

Figure 3-15. Stages of Energy Use in Water



Base Year and Inventory Frequency

In California, a base year of 2005 is preferable because it aligns with legislative goals such as AB 32 and SB 375. Unfortunately, complete fuel and electricity use records for past years were not readily available from the utilities addressed here. With that caveat, it is important to establish a year that has consistent and accurate data across all of the emitters in question. Based on these criteria, the year 2011 was chosen as a baseline for the Inyo-Mono region. In order to identify emission trends, such as the effects of deliberate efficiency and conservation measures or indirect effects (e.g., economic trends), inventories should be conducted at least every five years, although annual inventories are preferable. Going forward, we recommend that the water utilities actively track the sources identified in this inventory.

Quantifying Emissions

Quantifying GHG emissions follows a straightforward path: multiplying "activity data" by "emissions factors" and the Global Warming Potential (GWP). Activity data are the amount of fuel consumed, vehicle miles traveled, population served, etc., and emissions factors are the amount of each GHG emitted by each activity (e.g., burning fuel or driving miles). Global warming potential weights each of the GHGs in terms of strength and the amount of time they spend in the atmosphere. Each relevant fuel source and type is discussed below.

Direct Emissions (Scope 1)

Stationary Combustion

Stationary combustion is the burning of fuels within the region (water district) to generate heat or electricity. For water districts, this generally means remote generators or boilers to create heat for buildings or processes such as wastewater treatment.

Emissions for natural gas, propane and diesel are each calculated by multiplying the amount of fuel by the emissions coefficient for carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). Indian Wells Valley uses diesel for both stationary combustion and motor vehicles, but they do not break out these uses so all diesel emissions were calculated as mobile sources, as described next.

Mobile Emissions

Mobile emissions apply to the vehicles used by the utility districts to service and build infrastructure and to read water meters if applicable. Calculating CO_2 emissions is straightforward: gallons of gasoline and diesel were provided by each utility and those amounts were multiplied by the emissions coefficient for CO_2. Emissions of CH_4 and N_2O are more dependent on miles traveled and year and type of vehicle than gallons burned. June Lake provided mileage and vehicle year and type, so the emissions were calculated by multiplying miles driven by the appropriate emissions coefficients. Indian Wells Valley supplied gallons of gasoline and diesel, but not miles. Additionally, IWV uses diesel for stationary combustion and vehicles but does not differentiate them. For this inventory, all diesel emissions were calculated using the alternative mobile sources equations, based on gallons, with coefficients for CO_2, N_2O, and CH_4.

Wastewater

Direct emissions from wastewater treatment arise from the actual biologic process of decomposing the organic materials in wastewater when methane and nitrous oxide are released, and from on-site electricity or heat generation from burning fossil fuels. In the Inyo-Mono region, the three water utilities analyzed use aerobic digestion which releases negligible amounts of CH_4 and N_2O. In accordance with the Local Governments Protocol and the U.S. EPA, these negligible process emissions are not included in the inventories. Mammoth Community Water District burns some propane in their wastewater treatment plant for space heating, and these emissions are included in the MCWD inventory. On-site burning of natural gas and propane are calculated as above ("Stationary

Combustion”).

Indirect emissions from wastewater treatment include the purchased electricity and vehicle fuels used to in order to transport, treat, and dispose of wastewater and its byproducts. Indian Wells Valley sends their wastewater to the city of Ridgecrest for treatment. Those emissions are not included in this inventory. Mammoth and June Lake own their wastewater treatment plants, and the electricity purchased to run the plants are included in their respective inventories. The emissions from purchased electricity are calculated as described below (“Purchased Electricity”). Mammoth found that wastewater treatment was the district’s top single use of electricity and responded by installing a 1 megawatt solar array to offset that demand; see the Mammoth inventory for more details.

Indirect Emissions (Scope 2)

Purchased Electricity

Purchased electricity tends to be a large source of emissions, but is indirect because the fuels are burned at the power plant in another location while the electricity demand and use is in the water district. Nationally, the U.S. EPA maintains a database of region-specific emissions factors based on the mix of fuels (i.e. natural gas, coal, renewable, etc.) used at each power plant. Most California utilities, either in the past or currently, calculate a specific and more accurate emissions factor. Southern California Edison, the electricity provider to all of the water districts inventoried here, last updated their emissions factor in 2007, so that was the number used.

GHG Inventory Case Study: Indian Wells Valley Water District

Background

Indian Wells Valley Water District (IWVWD) is a medium-sized public water retailer, providing water to about 12,000 residential and commercial connections, totaling approximately 30,000 residents, in the Ridgecrest area of Kern and San Bernardino Counties, California. The district service area is approximately 38 square miles of the Indian Wells Valley, which lies in the northern Mojave Desert, southeast of the Sierra Nevada and south of Owens Valley (Krieger & Stewart 2011). The water source for Indian Wells Valley is a single aquifer, which is a naturally-occurring underground reservoir, and area residents and businesses pump nearly 30,000 acre feet (AF) per year, while replenishment from rain and snow is closer to 10,000 AF (Mulvihill 2008). The water district was incorporated in 1955, and groundwater levels have been dropping since the 1960s (IWVWD 2011).

Although seldom seen by the public, IWVWD has over 200 miles of pipeline as well as storage tanks, wells, pumping plants, boosters, arsenic treatment plants, and office headquarters. The District currently operates 10 active wells with capacities ranging from 1,000-1,400 gallons per minute (Mulvihill 2010). There are eleven storage tanks with capacities ranging from 100,000 gallons to 5 million gallons at strategic locations throughout the District, with at least one tank located in each of five service zones. The district’s largest recent capital investment (about $15 million) was to support two arsenic treatment plants.

Greenhouse Gas Inventory

Indian Wells Valley Water District has direct emissions from their vehicle fleet, gasoline and diesel, and burning of natural gas. Indirect emissions are a result of electricity purchased from Southern California Edison and wastewater treatment, which is carried out by the city of Ridgecrest. Greenhouse gas emissions for CO_2, N_2O, and CH_4 were calculated following the *Local Government Operation Protocol* developed and adopted by the California Air Resources Board, the California Climate Action Registry, ICLEI-Local Governments for Sustainability, and The Climate Registry (May 2010). See the methodology section for full details.

Fuel and electricity use records were available for 2011, so this will be the baseline year going forward. Year-to-date data are available for 2012, and the District is encouraged to update these numbers on a monthly basis. Wastewater treatment is by far the largest source of GHGs, largely due to the methane emissions from anaerobic digestion. Indirect emissions from purchased electricity are an order of magnitude larger than the direct emissions of diesel fuel use. Gasoline and natural gas, respectively, make up the rest of IWVWD's GHG emissions profile. Figure 3-16 shows the annual emissions for the baseline year of 2011, and Figure 3-17 shows the monthly emissions for 2011. In the first three months of 2012, emissions are down 16.5% from 2011 emissions, largely because of an almost 50% decrease in gasoline and diesel use. Figure 3-18 shows GHG emissions by activity (water production, administration, etc.)

Figure 3-16

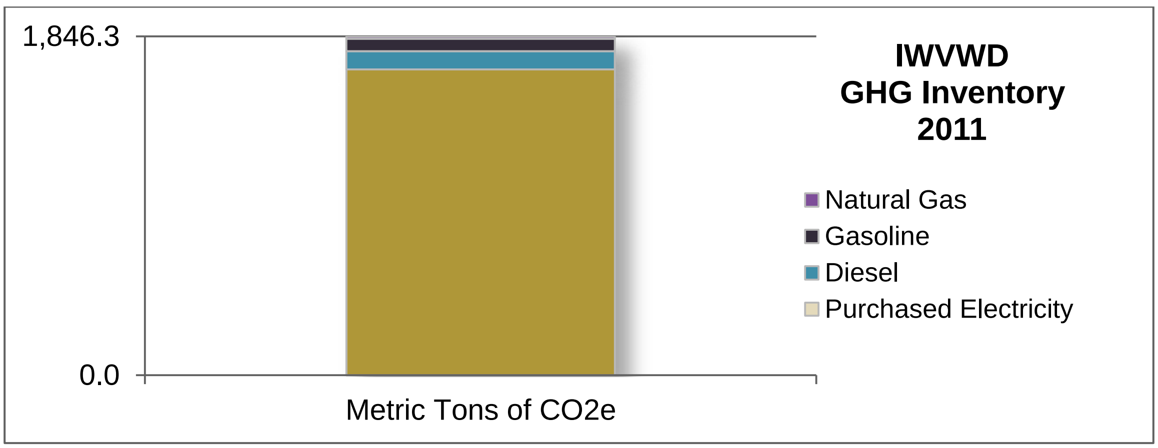


Figure 3-17

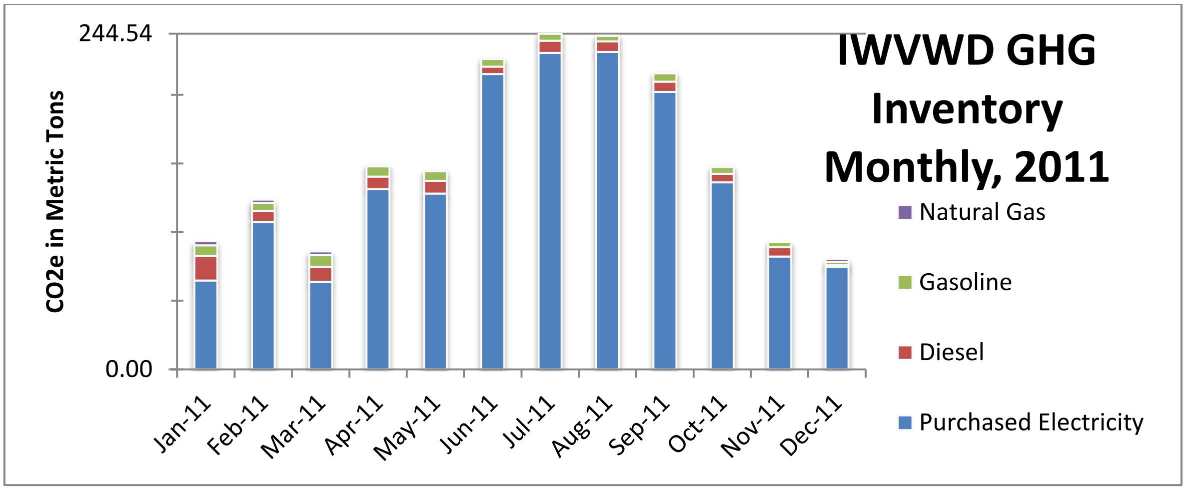
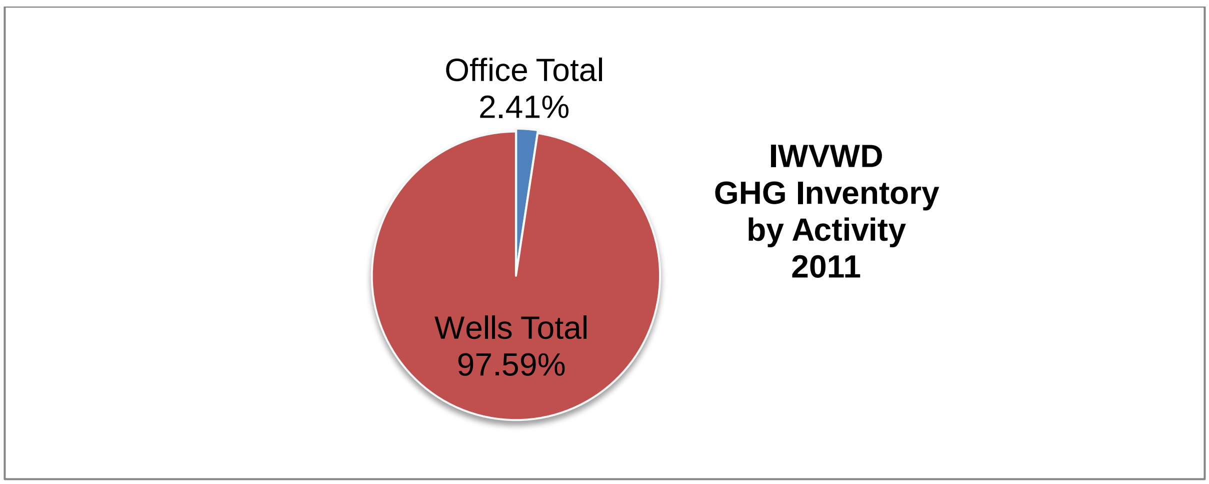


Figure 3-18



GHG Inventory Case Study: June Lake

Background

The June Lake Public Utility District (JLPUD) serves a full-time residential population as well as a substantial visitor population. The district provides water treatment and distribution, sewer collection and treatment, and mosquito abatement services (Mono County LAFCO 2009). According to the 2010 census, the year-round residential population of the town of June Lake is approximately 629 people, while the seasonal visitor population peaks at approximately 2,500 people-at-one-time for a plethora of winter and summer recreational activities (U.S. Census 2010). The JLPUD's water consumption is difficult to predict accurately. The fluctuating tourist population and the small permanent population, along with weather conditions and the economy, all contribute significantly to the oscillating water consumption (Mono County LAFCO 2009). According to the Rodeo Grounds Water Demand Project, which can serve as a proxy for the rest of JLPUD's service area, peak winter months are from December through March (averaging 2,000,000 gallons per month), while peak summer months are June through

September (averaging 4,000,000 gallons per month) (Hansford 2006). Peak summer months double the amount of water used each month due to increased residential use and resort irrigation. The Mono County General Plan section specific to June Lake concludes that estimated water demands are expected to peak only for a few days per year, and the system has been designed to meet those peak demands. However, the water system may not be able to meet the projected maximum month-average day demand at build-out (Mono County LAFCO 2009).

The JLPUD provides water and sewer service to an area of 1,720 acres within the June Lake Loop (Highway 158 to the west of Highway 395). The June Lake Loop houses a majority of the developed community and is situated against the west rim of the Great Basin and Range Province, adjacent to the steep eastern escarpments of the Sierra Nevada. The Inyo National Forest allotted surface water diversion rights to the JLPUD for both the Village System and the Down Canyon system, totaling approximately 1,116,000 US gallons per day, which is serviced by almost nine miles of pipes (Mono County LAFCO 2009). Both the Village System and the Down Canyon System have sufficient storage capacity to meet existing and fire flow demands, although the Water Master Plan recommends that both systems build 500,000-gallon reservoirs to meet future demands at build out (Mono County LAFCO 2009). The utility district provides sewer service to three major service areas: the June Lake Village, Down Canyon areas of June Lake, and U.S. Forest Service campgrounds. The sewer system currently includes 14 miles of pipeline, 29 lift stations, 5 pump stations, and the wastewater treatment plant. The treatment plant provides secondary improvements to the system to meet current and projected future demand (Mono County LAFCO 2009).

Greenhouse Gas Inventory

June Lake Public Utility District has direct emissions from their vehicle fleet, which largely uses gasoline. They do not track the minimal diesel use. Indirect emissions are a result of electricity purchased from the utility Southern California Edison and wastewater treatment, which is carried out by the utility district itself. The district does not use any other fuels directly (i.e. propane, natural gas). Greenhouse gas emissions for CO_2, N_2O, and CH_4 were calculated following the *Local Government Operation Protocol* developed and adopted by the California Air Resources Board, the California Climate Action Registry, ICLEI-Local Governments for Sustainability, and The Climate Registry (May 2010). See the methodology section above for more details.

Full fuel and electricity use records were available for 2011, so this will be the baseline year going forward. Year-to-date data are available for 2012, and the district is encouraged to update these numbers on a monthly basis. Electricity purchased from Southern California Edison is the largest source of GHGs, followed by wastewater treatment (largely methane emissions), and gasoline used in the small vehicle fleet. Figure 3-19 shows the annual emissions for the baseline year of 2011, Figure 3-20 shows the monthly emissions for 2011, and Figure 3-21 breaks down electricity emissions into water and sewer categories (a negligible amount is used for administration and maintenance buildings). In the first three months of 2012, emissions are up about 8% from 2011, largely due to an almost 38% increase in gasoline use.

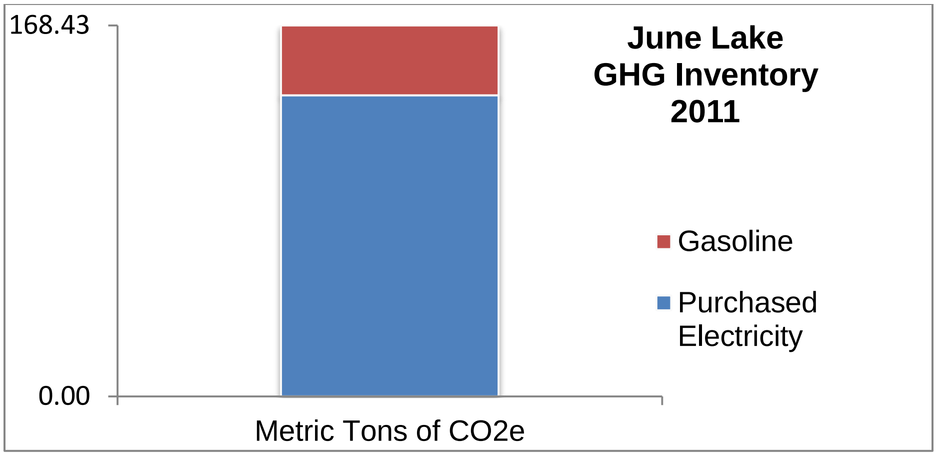


Figure 3-19

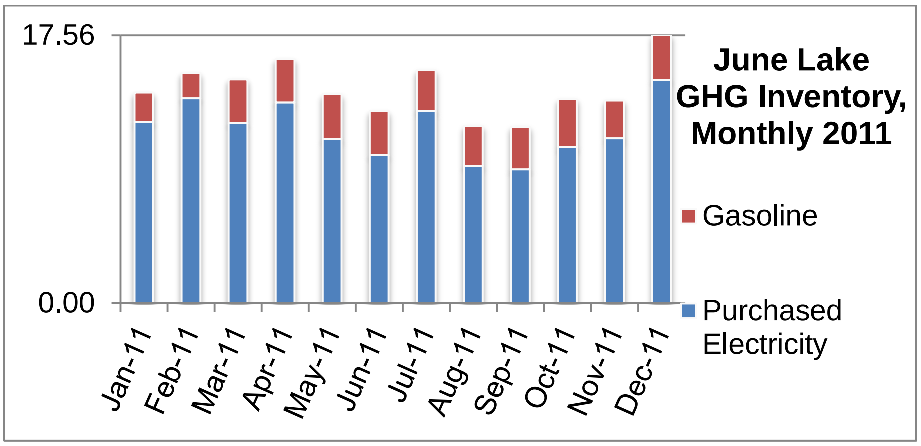


Figure 3-20

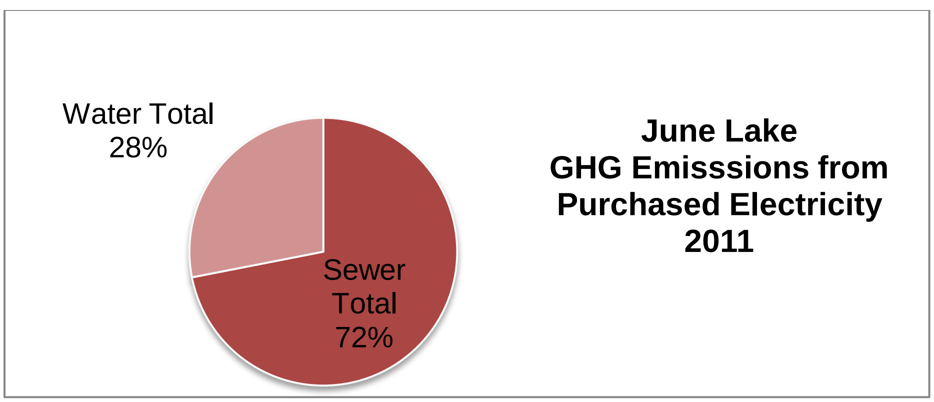


Figure 3-21

GHG Inventory Case Study: Mammoth Community Water District

Background

The Mammoth Community Water District (MCWD) provides water and sewer services to the Town of Mammoth Lakes in Mono County, California. This small resort community is located on the eastern slope of the Sierra at an elevation of approximately 8,000 feet above sea level. The economy of the area is primarily based on recreation and tourism, and visitation is bimodal between the winter ski season and the summer recreation season. Mammoth Lakes has a year-round population of about 8,500, but during peak tourism the population swells to about 35,000 people (US Census 2010, Town of Mammoth Lakes 2007). Most of the area's precipitation comes as winter snowfall, with the area receiving an average of about 17 feet of snow (equating to approximately 24 inches of water) annually (1993-2010; MCWD 2010). The population and precipitation seasonality creates an interesting set of water management considerations and is visible in the water district's emissions profile.

The MCWD provided fuel and electricity use data for the years 2008-2011, broken down into water supply, wastewater treatment, and administration. The district also provided data on water supply and wastewater treatment. Tracking emissions along with the amount of water delivered allows us to looks at "emissions intensity," metric tons of greenhouse gas emissions per millions of gallons of water. Not only does the emissions intensity provide a more detailed view of the district's efficiency, but it allows a direct comparison between water utilities.

Greenhouse Gas Inventory

The Mammoth Community Water District has direct emissions from their vehicle fleet and on-site burning of propane for space heating. Indirect emissions are a result of electricity purchased from Southern California Edison, as well as wastewater treatment carried out by the water district itself. The MCWD treats its wastewater aerobically; therefore, process emissions from wastewater treatment are considered negligible and not included in this inventory. Greenhouse gas emissions for CO_2, N_2O, and CH_4 were calculated following the *Local Government Operation Protocol* developed and adopted by the California Air Resources Board, the California Climate Action Registry, ICLEI-Local Governments for Sustainability, and The Climate Registry (May 2010). See the methodology section for full details.

The GHG inventory for MCWD reveals a number of interesting trends and highlights some of MCWD's efficiency measures. Figure 3-22 shows GHG emissions for all of MCWD's activities from 2008 through 2011 as bar graphs, and the amount of water procured and treated as a line graph. Purchased electricity is the largest single source of emissions and is also where the district has made the most efficiency gains. Between 2010 and 2011 in particular, the district successfully reduced its electricity demand while maintaining approximately the same level of water supply and treatment, largely due to the focus on maximizing the use of surface water. Surface water is gravity-fed, thereby decreasing demand for electricity for groundwater pumping, and saving MCWD a significant amount of money. In fact, many days the district is able to completely shut off pumps between noon and 6pm, when electricity is the most expensive. In 2008, 50% of the electricity used was for water supply and 45% was used for wastewater treatment, with the last 5% used in administration buildings. In 2011, only 19% of the electricity was used for water supply while 73% and 8% was used for wastewater and administration, respectively. This shows the large effect that water management decisions can have on energy use. Figure 3-24 shows emissions by activity for 2011. The district is now focusing on reducing GHG emissions from wastewater treatment by installing solar panels (see case study) and increasing efficiency in the administration category by following recommendations provided from a recent energy audit.

Looking at monthly emissions from 2011 (Figure 3-23), water supply and treatment spikes during the winter and summer due to increased recreation population. Emissions increase in the summer as surface water begins to dwindle and the district must pump more groundwater. Gasoline and diesel used in the district's vehicle fleet is included in administration and these emissions spike in the summer when the majority of construction and maintenance takes place. In the winter, propane is used for heating, which drives the higher emissions seen in the cold winter months. October is generally the least water- and emissions-intense month because there is virtually no tourist population in Mammoth Lakes, and there is little outdoor water use as the short growing season ends.

As 2012 data become available, MCWD will update the charts and graphs. The Inyo-Mono RWMG will follow up with MCWD to determine how the solar panels and energy audit have affected the amount of electricity purchased by MCWD and the resulting emission inventory. By reducing electricity demand through water management and technical upgrades, MCWD successfully decreased the amount of electricity it needs to deliver water, and by generating clean energy on-site, the district is able to reduce GHGs on the supply side.

Figure 3-22

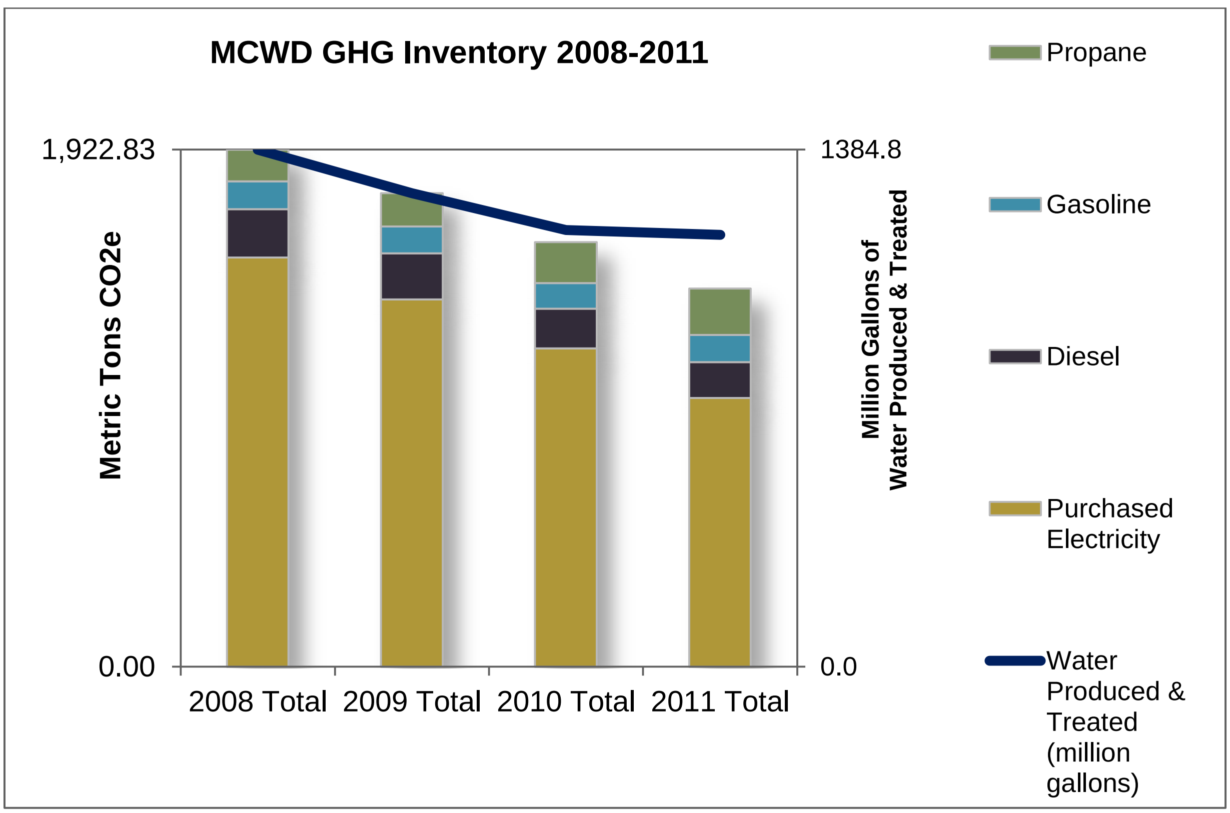


Figure 3-23

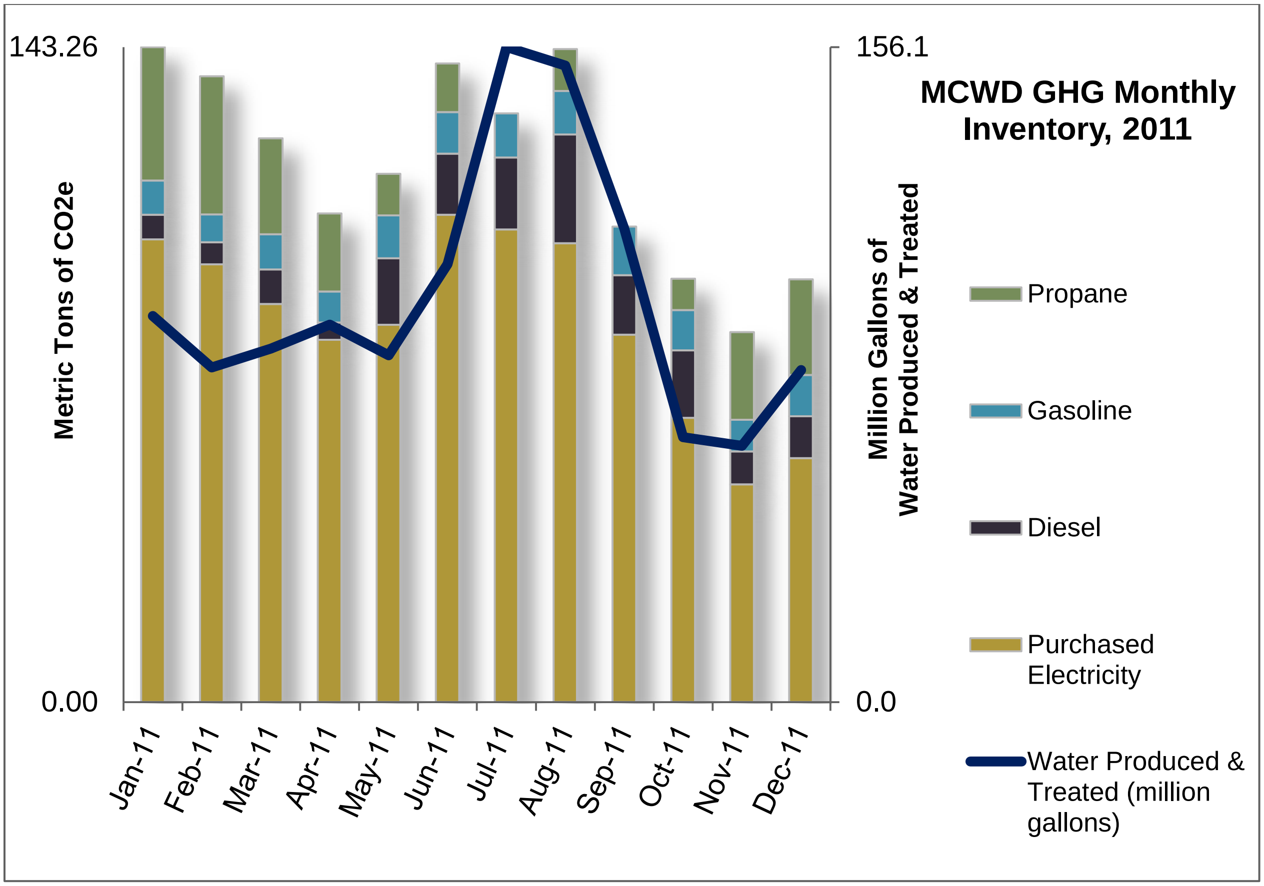
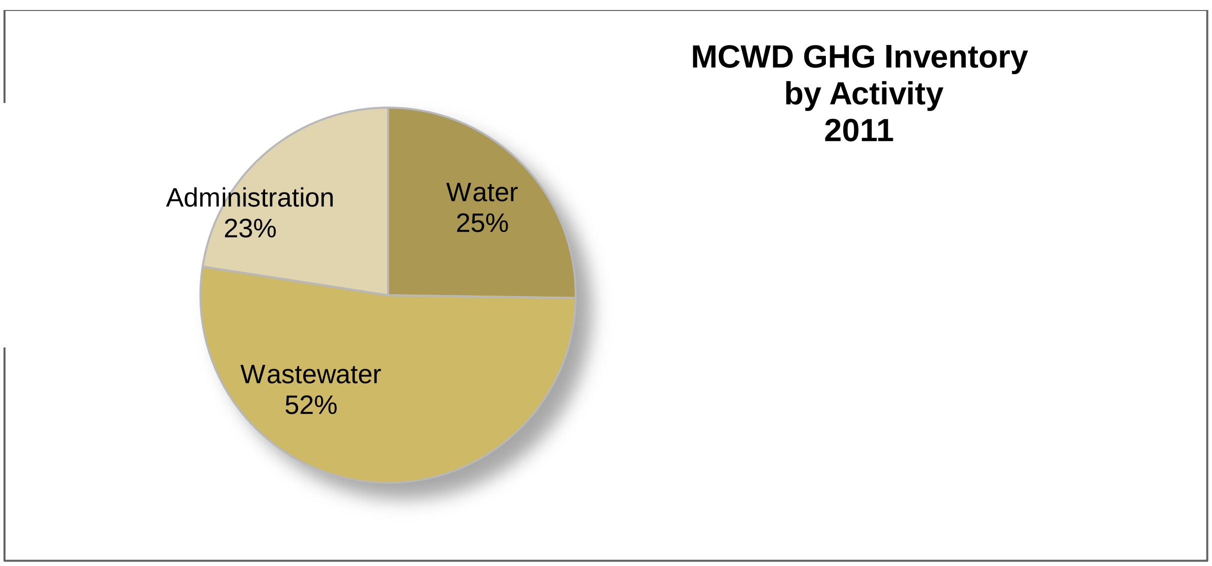


Figure 3-24



Case Study: Mammoth Community Water District's Solar Array

Up front cost: $5.5 million

Estimated payback period: 9 years

Life of solar panels: 20 years

State and Federal Incentives: $3.5 million

MCWD 1MW Solar Photovoltaic Power Plant

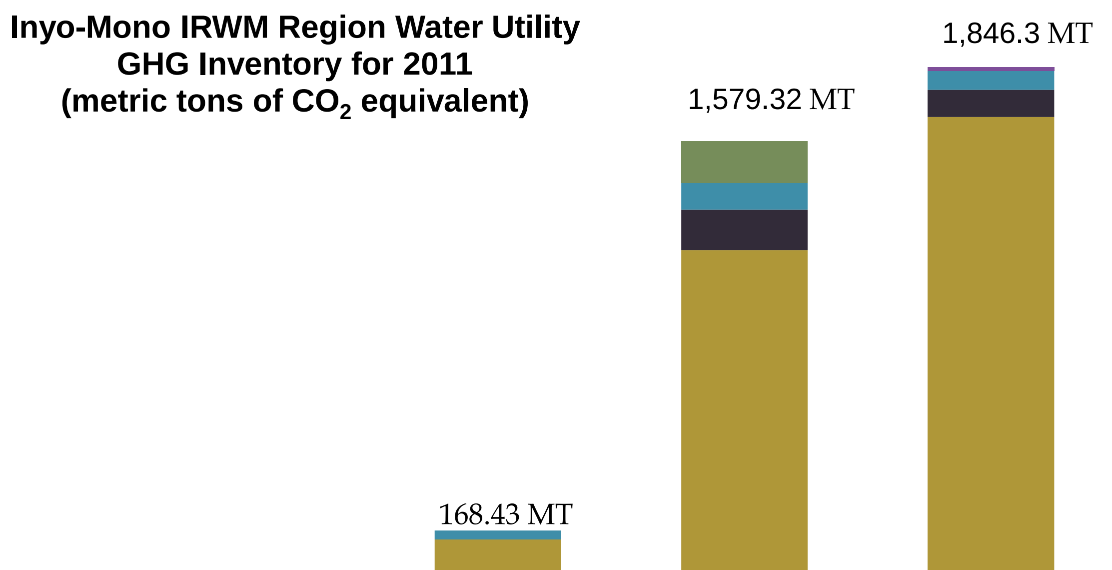
In 2009, the MCWD Board began discussing the possibility of installing arrays of solar panels on or around its property in Mammoth Lakes. The largest single demand for electricity is the wastewater treatment plant, costing about $17,000 per month to power. In order to save costs and reduce its environmental impact, the MCWD Board started discussing the possibility of installing solar panels in 2009. There is not enough roof space on MCWD buildings to support a large solar array, so MCWD staff decided to site the project on a retention pond. The three acre site covers the emergency overflow pond as well as some adjacent land and, rated at 1 megawatt, covers about 80% of the electricity load for the wastewater treatment plant. The four large arrays of solar panels follow the sun and automatically lay flat in high winds to protect the panels from damage. Due to the cutting-edge design of the panels and the cool weather and clear skies, the system has been performing at about 115% of expected power generation since the system went live in October, 2011. The water district considered a number of ways to pay for the system but in the end was in the fortunate position to be able to pay the upfront costs. Including state and federal incentives, the system should pay for itself within nine years. The panels have a life expectancy of about 20 years, but the framework is expected to last longer and will be able to support more advanced solar panels as they become available and affordable.

For more information: http://www.mcwd.dst.ca.us/Solar Page/MCWDSolar.htm

Comparison of Three Water Districts

Figure 3-25 shows the GHG inventories for the three water utility districts in the baseline year of 2011. A direct comparison of gross 2011 GHG emissions is misleading given the significant disparity in size among the three water districts, but it is instructive to see emissions quantified and sources identified. A common metric must be used in order to fairly compare the three districts' GHG emissions. Emissions per population served would be convenient, but due to the large seasonal population swings, especially in June Lake and Mammoth Lakes, this is not a reliable method. Emissions per amount of water (metric tons of CO_2-equivalent emissions per million gallons of water procured and wastewater treated) may be a better common metric, but as the Mammoth Community Water District inventory details, the source of the water each district relies on (groundwater vs. surface water) largely determines how much electricity is needed to extract the water. In future IRWM Plan updates, we will explore the idea of finding a common metric, possibly by using the amount of water handled by each district or integrating monthly populations, if either of those data are available, or some other metric discovered through a more extensive literature review.

Figure 3-25. Comparison of emissions inventories for the three water systems



	June Lake Public Utility District	Mammoth Community Water District	Indian Wells Valley Water District
Propane	0.00	152.25	0.00
Natural Gas	0.00	0.00	12.16
Gasoline	31.79	95.54	68.39
Diesel	0.00	147.06	98.98
Purchased Electricity	136.64	1184.48	1666.76

Next Steps

As discussed above, 2011 will serve as the baseline year for GHG emissions. It is important to collect energy use data at least annually in order to track progress and minimize the time and cost required to conduct inventory emissions. Actively compiling the data in a form such as Excel, on a monthly basis, will further reduce the time needed at the end of the year while allowing real-time tracking of emission-reducing measures.

Based on emissions inventories, water districts can pinpoint the largest sources of emissions and the most energy-intensive activities. This information can help prioritize projects in order to reduce emissions for the region and save money for the water districts. A key outcome of emissions tracking and identifying successful emissions-reduction measures undertaken by water districts in the Inyo-Mono IRWM region will be information sharing and mutual assistance among area water purveyors.

Finally, by identifying the energy use data and district-specific information needed, and by working through the three case studies included in this inventory, a proof-of-concept was developed. With the knowledge gained, it will be faster and easier to help similarly-sized districts inventory their emissions.

Moving forward, the Inyo-Mono RWMG would like to explore and test methods to help and encourage smaller water districts, as well as households and communities on individual wells and septic systems, to inventory their water-related emissions. Additionally, referring back to Figure 3-15, inventorying water-related emissions at the end user point (e.g., water heating) would help to paint a more complete picture of the energy embedded in water. A more detailed description of the water-energy nexus in the Inyo-Mono region will more fully inform water management and allow the IRWM Program to continue to act as a model for the Sierra and similar rural, mountain regions.

Carbon Sequestration

Carbon sequestration is a climate change mitigation action that aims to remove carbon dioxide from the atmosphere and store it in vegetation or soils. In regions with climates that support carbon-rich soils, or that have a large potential for reforestation, carbon sequestration may be a viable option for mitigating GHG emissions. Due to the very dry climate and relatively sparse vegetation in the Inyo-Mono region, soils hold little organic matter and have high mineral content. Thus, soil sequestration is not a viable option. Carbon sequestration in vegetation also does not hold much promise in this region. There has been little deforestation due to logging and other anthropogenic disturbances, so there is little opportunity for reforestation. Furthermore, most of the forests in the region are overgrown due to fire suppression, so they will likely become a source of carbon emissions rather than a sink. It seems that the best option for mitigation of GHGs in the region is to reduce emissions from the sources.

Conclusion

The Inyo-Mono RWMG and Program Office staff will continue to work to understand the potential (and current) impacts of climate change in the region as well as options for responding to those impacts. A key need for water and land managers in the region is better access to up-to-date climate change information, as well as information (such as models) developed on scales appropriate for land and water management and planning. The RWMG will continue to serve as a liaison between agencies and institutions producing information, and agencies and organizations requesting that information.